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Proposed Sustainable Hydropower Generator in Sitio Madalumdum San Pedro, Sasmuan, Pampanga

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Abstract:

In the Philippines, there is a noticeable surge in electricity demand due to the rising heat index. More households turn to cooling systems like air conditioning to beat the heat. This increased usage of electricity puts pressure on the grid, emphasizing the importance of finding sustainable solutions to keep up with growing energy needs. This study used a hydro powered generator to provide Sitio Madalumdum, San Pedro Sasmuan, Pampamga a solution to their energy needs. Utilizing Sitio Madalundum's natural resources, data collection was conducted and analyzed to support the study. The general design of the dam was explained. After finalizing the design, the construction of prototype began. The study used the water wheel concept, the researchers used a 5V DC motor that is connected to an LED bulb. The prototype successfully lit a 0.5 watts LED bulb with the assistance of pulley system. Pico-hydropower's standard efficiency was implemented, and that is about 60% - 80%. The researchers started the prototype testing, by testing the voltage using the multimeter, the average actual voltage obtained is 1.034V. The minimum theoretically efficient power calculated is 0.0427W, and the maximum is 0.0572W. The study aimed to generate electricity that is not lower than the minimum and as close as possible to the maximum to determine the design's efficiency. The actual power generated, is 0.0517W, falling within the range of the calculated minimum and maximum efficient power, which made the design 72.61% efficient.

Keywords **—Efficiency, prototype, pulley system, theoretical power**

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1. THE PROBLEM AND REVIEW OF RELATED LITERARURE

1.1 INTRODUCTION

Electricity consumption is an indicator of a nation’s economic development and its quality of life. In the Philippines, as it is a rapidly growing country with its population, urbanization, and economic expansion have contributed to a significant increase in electricity use over the years. With its growing population, the need for energy continues to increase. The Philippine electricity prices have been among the highest in Southeast Asia. The Philippines, an archipelago of 7, 461 islands faces challenges as most of its islands are inaccessible to larger electric-grid infrastructure. These islands are often served by mini-grids powered by generators. The true cost of service on these island systems is much higher than those on the main Philippine grids [1].

The pursuit of harnessing renewable energy through sustainable hydro-powered generator aligns closely with the United Nations' Sustainable Development Goal (SDG) 7: Affordable and Clean Energy. The 2030 Agenda for Sustainable Development was adopted by all United Nations members in 2015. This is a shared blueprint for peace and prosperity for people and the planet. It has 17 Sustainable Development Goals (SDGs), which are an urgent call for action for developed and developing countries. According to the United Nations, 675 million people still live in the dark, so one of its targets is to ensure universal access to affordable, reliable and modern energy services and increase substantially the share of renewable energy in the global energy mix by 2030. By focusing on the utilization of renewable energy for power generation, this study contributes directly to the broader global initiative of promoting clean and affordable energy sources. The technology not only aligns with the goal's emphasis on clean energy but also addresses the need for innovative solutions to meet the increasing demand for power without exacerbating environmental impacts [2].

According to Justice Antonio T. Carpio, a former senior associate justice of the Supreme Court of the Philippines, the Philippines is facing a possible shortage of electricity due to the conflict in the West Philippine Sea. The region is rich in energy resources, and the Philippines is keen to develop these resources to meet its growing energy needs. The territorial dispute with China has caused tensions and confrontations in the area, which makes it challenging for the Philippines to access these resources. One of the key areas of contention is the Reed Bank, which is rich in gas and is a critical source of energy for the Philippines. The Philippines is also concerned that the Malampaya gas field, which currently supplies 40 percent of Luzon's energy requirement, will soon run out of gas. To counteract the potential shortage, the Philippines is searching for alternative energy sources in light of these challenges.

The Philippines was hit hard in April 2024 because of a heatwave and deteriorating power supplies. This has led to power outages across various regions, leaving them without electricity for hours or even days. As the temperature rises, the demand for electricity has placed pressure on the already strained power grid. The National Grid Corporation of the Philippines (NGCP) has issued frequent yellow alerts across Luzon and Visayas grids which means that it has low reserves that risk power disruptions if conditions deteriorate. According to Inquirer.net, As of April 25, Luzon’s power availability was recorded at 14,568 MW, nearly overtaken by a peak demand of 13,941 MW, illustrating the thin margins between its supply and demand. As the nation's main power grid has been put on "red alert" for the second time this week, forcing customers to brace for the possibility of rotational brownouts. According to NGCP, there are still 19 electric generating units in the Luzon grid that are experiencing forced outages, and one of them has its capacity significantly reduced, deducting 1,891.3 megawatts from the grid's total capacity [3].

In an era marked by environmental challenges and a growing demand for energy, the shift towards renewable sources has emerged as hope. Renewable energy, derived from natural resources like sunlight, wind, and water, offers a sustainable alternative to fossil fuels. Renewable energy sources are critical to our future, as its adoption is not merely just a technological fix for a lower electricity rate but a moral and environmental necessity.

According to Quaranta&Revelli [4], using renewable energy sources for electricity generation at large scale has become an important way of meeting renewable energy targets and for reducing greenhouse gas emissions. However, it is estimated that only 8% of the world's energy consumption is generated from renewable sources, while 92% comes from non-renewable ones.

Hydropower is one of the oldest and largest sources of renewable energy, which uses the flow of moving water to generate electricity. While some people associate hydropower with large dams, hydropower facilities come in all sizes. Water, abundant and omnipresent, possesses the potential to drive turbines and generators, providing a perennial source of clean and reliable energy [5].

There are, however, a number of difficulties faced with the expansion of large hydropower projects. It is difficult to further develop large hydropower projects due to the potential of upstream flooding, destruction of agricultural areas and animal habitats. Given these issues with large hydropower projects, a lot decided to focus on smaller and manageable projects [6]. Microhydropower systems usually generate up to 100 kilowatts of electricity. A 10-kilowatt micro hydropower system generally can provide enough power for a large home, a small resort, or a small farm [5].

There are several obstacles to Bangladesh's economic development, including the depletion of fossil fuels and the difficulty of providing the country's growing electrical demand. The nation is likewise concerned about the carbon emissions caused by the developed nations. Because Bangladesh has so many rivers and canals, it offers off-grid power to both remote and still-off-grid locations. This article focuses on the possibilities of micro-hydropower plants in Bangladesh. This essay examines Bangladesh's present energy situation and the necessity to investigate green energy sources in order to demonstrate how the development of widespread micro-hydropower plants might aid in resolving the nation's current power problem and further its economic development. ls, head calculation, topographic studies. The possible locations that are now available are listed, and methods for finding new sites—such as hydrological studies, topography studies, head calculations, turbine selection, and other methods—are described [7].

The focus of this thesis is the development of a water system that utilizes renewable energy sources to generate power sustainably in Sitio Madalumdum, San Pedro, Sasmuan, Pampanga. This system, referred to as a hydro-powered generator, has the potential to revolutionize the way power is generated in various applications, mainly rural electrification.

This study aims to investigate the feasibility of utilizing hydro-powered generator as a means of harnessing renewable energy for power generation. This research will explore the design of the generator, with a particular emphasis on energy efficiency.

1.2 REVIEW OF RELATED LITERATURE AND STUDIES

1.2.1 Renewable Energy and its types

Fossil fuel takes 100 million years to produce, and with our current pace of use, we would use it all up in 100 years. It is paradoxical that despite our plenty, we are still unable to fully utilize solar energy. In an hour, sunlight provides more energy than the earth needs in a year. Exploiting solar energy's potential requires technological innovation. Because conventional energy sources are used so extensively nowadays, fossil fuels will run out by 2050, while coal will still be around for another 200 years. 70% of the energy produced worldwide is consumed by 22% of the population who live in wealthy countries. Even with the significant advancements, 25% of the global population still lacks [8].

There are many alternative ways to produce energy, including renewable sources and innovative technologies. Solar power is a type of renewable energy that has gained popularity in recent years due to its advantageous features such as availability, reliability, and environmental friendliness [9]. Solar power works when the sun shines onto a solar panel, energy from the sunlight is absorbed by the PV cells in the panel. This energy creates charges that move in response to the electric field inside the cell, causing current to flow. This electrical energy can be used to generate electricity or be stored in batteries or thermal storage [5].

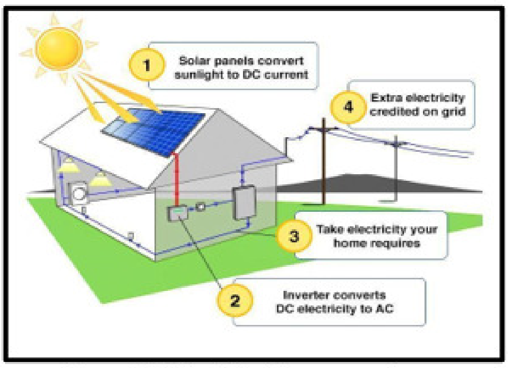


Figure 1.1 How Solar Energy works

Source: philsolar.ph

Wind is a widely available source of energy. Wind energy is a green energy source because wind turbines do not directly create emissions, helping countries achieve their goals of reducing emissions and combating climate change. The consumption of wind energy has been shown to reduce CO2 emissions [10]. Wind energy has lower maintenance and operating costs than nuclear energy.

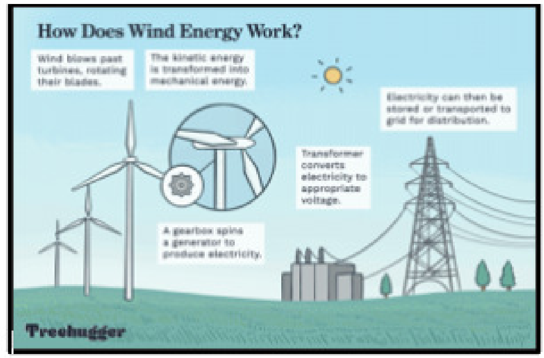


Figure 1.2 How Wind Energy works

Source: treehugger.com

Cleaner production techniques are necessary given the rising environmental consciousness and corresponding rise in electricity use. Effective energy storage strategies enable the employment of more environmentally friendly electricity generation processes. The most developed renewable energy storage technology available today is hydropower, which generates 16.3% of the world's electricity. Water resources are primarily reliant on hydropower [11].

1.2.2 Hydropower

Non-renewable energy, such as fossil fuel, continues to be the biggest source of energy. Recently, programs of developed nations have emphasized the importance of renewable energy in finding solutions not only to the power supply but also to the problems caused by climate change. As an archipelago, the Philippines has a rich resource for hydropower from its rivers, lakes, waterfalls, and seas. Utilizing these natural resources is the primary concern of this paper, specifically the river current which is particularly influenced by gravity as the elevation of a certain area changes. The study is embodied by its advocacy to minimize pollution in the environment. The findings of this study could be a solution for communities without electricity or for communities near rivers but not yet reached by electriclines[12].

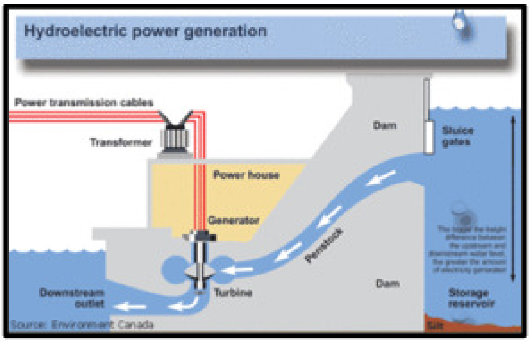


Figure 1.3: How Hydro Energy works

Source: USGS.gov

According to the Department of Energy [6], the Philippines has a vast untapped hydropower potential, estimated at 13,097 MW, of which 85% is considered large and small hydros. Under the National Renewable Energy Program, the country aims to triple its renewable energy capacity by 2030, requiring an additional 8,700 MW of hydropower [13] (Andritz A.). The government is also seeking to develop and commercialize suitable micro-hydro technology in the Philippines, as the country remains dependent on imported electro-mechanical equipment for micro-hydro projects [6].

The project study concentrated on the design and construction of an energy converter that makes use of the currents and flow of water in tiny bodies of water such streams, rivers, channels, inlets, waterways, and even canals. Through field testing, the advocates discovered that the symmetry between the mechanical and electrical components had a significant impact on the power produced and the efficiency of the prototype. To attain the best level of efficiency, the mechanical parts, such as the chain-sprocket mechanism, must have the appropriate number of teeth, and the blade area must have the ideal size, number, and weight. The motor needs to have the most windings possible in order to produce a lot of electricity. The project's goals were to ascertain the technical requirements needed to harvest energy from water currents, ascertain the design and capacity of the energy converter that will harvest energy from water currents, and ascertain the estimated cost for the project's fabrication [14]

The study designed a hydroelectric power plant in Pasbul Aeta community, Porac, Pampanga. They used the available water source which is the Camias River. The study used a Reaction turbine specifically the Kaplan turbine, which is more suitable for low-head (2-30m) sites than the Francis turbine [15].

According to Bacani G. Et al., [16], To solve the electrical issue with the streetlight system in Barangay Camias, Porac, Pampanga, pico-hydropower was employed. This use of pico-hydropower shows how small-scale hydropower systems may supply dependable and sustainable electricity for community infrastructure.

Small towns can receive electricity from micro-hydro, or hydro energy on a "small" scale, which transforms hydro energy into electrical energy. This paper provides an overview of the micro-hydro system by going over some of its fundamental parts, like the generator and the turbine, which enable this conversion process. The fundamentals of micro-hydro systems will also be covered, including planning, benefits, and limitations as well as the estimation of micro-hydro energy potential, which depends on head and flow rate [17].

In 2017, based on Connie Bayudan's findings [18], the Household Energy and Consumption Survey conducted by the Philippine Statistics Authority in 2011 revealed that electricity is the primary energy source preferred by the majority. About 89% of urban households and 75% of rural households utilize electricity.

According to Matteo Postacchini et. al. [19], Pump-As-Turbine (PAT) is a technology that is capable of producing electricity in a sustainable way. Their experimental findings confirm the good performance of the PAT system, especially when the rpm and flow rate is larger than 850 rpm and 8 L/s it will result in having an efficiency greater than 50 percent.

1.2.3 Materials

According to Potential Engineering [20], the sluice gate is also known as a penstock or slide gate, is a vital component used to regulate fluid flow and isolate fluids in various applications such as water management, sewage treatment, power generation, irrigation, and industrial processes. Selecting the right sluice gate is crucial to meet design requirements and ensure cost-effectiveness. Modern sluice gates are designed to handle a wide range of conditions, from low-seating to high-off-seating heads, and are available in sizes ranging from 150mm to 2000mm. They come in circular, rectangular, or square shapes. The operation of a sluice gate can be simple, using a handwheel, or more complex, involving electrical, pneumatic, or hydraulic systems for actuation.

The chute spillway, also known as a trough spillway, is a vital structure for managing excess water flow. This chapter discusses its components and design considerations. It focuses on the hydrologic, hydraulic, and structural aspects of chute spillways. Hydraulic design includes elements like the entrance channel, control structure, chute channel, and outlet. Structural stability is analyzed considering the structure's weight and uplift pressure. The chapter provides a detailed procedure for stability analysis, showcasing the importance of proper design for safety and efficiency in water management [21].

A synchronous generator, also known as an alternator or AC generator, converts mechanical power into AC electric power through electromagnetic induction. It must be driven at synchronous speed to produce AC power of the desired frequency. Synchronous generators can be single-phase or poly-phase (typically 3-phase) [22].

1.2.4 Summary and Gap Analysis

This research bridges the gap between This research bridges the gap between existing research and technology concerning the development of hydropower generators for sustainable power generation in Sitio Madalumdum, San Pedro, Sasmuan, Pampanga. With an emphasis on renewable energy sources, the integration of hydropower generators presents an amazing avenue for harnessing hydropower. The research aims to identify limitations and propose innovative solutions for a more sustainable and reliable power generation system.

1.3 BACKGROUND OF THE STUDY

Electricity access is essential for economic development, education, healthcare and quality of life. However, many remote and marginalized communities in the Philippines, like Sitio Madalumdun in San Pedro, Sasmuan, Pampanga still lack reliable electricity. The lack of electricity limits their modern economic activities.

The National Electrification Administration (NEA) has estimated that as of 2020, 2.3 million Filipino households, many situated in remote areas do not have access to power. Sitio Madalumdum is one of these areas and has 13 households. The area's coastline location and reliance on boat as their transportation may make it more difficult to provide electricity from the power grid [23].

By implementing a sustainable hydropower generator in Sitio Madalumdum, the community can achieve a reliable and environmentally friendly source of electricity. This has the potential to greatly raise people' standard of living, expand their economic options, and support the region's general sustainable growth.

1.4 STATEMENT OF THE PROBLEM

In the context of developing a Hydro powered generator for Sustainable Power Generation in Sitio Madalumdum, San Pedro, Sasmuan, Pampanga, a critical challenge lies in ensuring the efficient sourcing and optimal flow of water for the system to function effectively. The viability of a sustainable generator heavily depends on maintaining a reliable and consistent water supply to generate power. The key problem addressed in this study is the need for consistent flow of water, as well as the pressure of water for the mechanism to operate effectively, thereby maximizing energy output. This research aims to address these challenges by investigating innovative solutions to optimize water intake and flow, ensuring the reliability and efficiency of the Hydro-powered generator for Sustainable Power Generation.

1.5 STUDY AREA

Figure 1.4. Map of Sasmuan, Pampanga

According to PhilAtlas [24], Sasmuan, formerly known as Sexmoan, is a coastal municipality in the province of Pampanga. The municipality has a land area of 91.80 square kilometers or 35.44 square miles which constitutes 4.59% of Pampanga's total area. Its population as determined by the 2020 Census was 29,076. This represented 1.19% of the total population of Pampanga province, or 0.23% of the overall population of the Central Luzon region. Based on these figures, the population density is computed at 317 inhabitants per square kilometer or 820 inhabitants per square mile.

In this study, the researchers maximize the flow in river near Sitio Madalumdum, San Pedro, Sasmuan, Pampanga by narrowing the path of water to produce certain flow for the Hydro Powered Generator. The flow of water will be use for the rotation of the turbine and production of electricity. The findings of this study have identified a potential source of renewable energy for the daily use of the residents in Sitio Madalumdum, San Pedro, Sasmuan, Pampanga.

Figure 1.5. Map of Sitio Madalumdum San Pedro, Sasmuan, Pampanga

This research focuses on Sitio Madalumdum, located within Barangay San Pedro in the municipality of Sasmuan, Pampanga. According to data provided by PELCO II, Sitio Madalumdum, a remote and unenergized coastal area in Sasmuan, Pampanga, consists of only 13 households. The primary challenges identified by PELCO II include the absence of road access and its 3.33 km distance from the nearest PELCO II distribution line. Transportation to this area is solely available by boat.

1.6 OBJECTIVES OF THE STUDY

1.6.1 General Objective

The general objective of this study is to develop an efficient and reliable generator capable of harnessing renewable energy from water sources for sustainable power generation without using fossil fuels.

1.6.2 Specific objectives

- To design a hydro powered generator capable of efficiently harnessing energy for sustainable power generation.
- To optimize the system for sustainability, ensuring minimal external energy input for operation
- To evaluate the efficiency of the hydro powered generator in converting water energy into electrical power.

1.7 SIGNIFICANCE OF THE STUDY

The outcomes of this study will be useful for the environment, community, government, and future researchers as this will provide information regarding harnessing renewable energy through sustainable hydro powered generator.

Community

This study will be a huge help to provide electricity to unenergized communities.

Government

This study will help them to evaluate the importance of Renewable energy and help the communities who don't have enough energy resources.

Future Researchers

The data and methods used in this paper may be used as a reference and serve as a guide for conducting new research and their future studies.

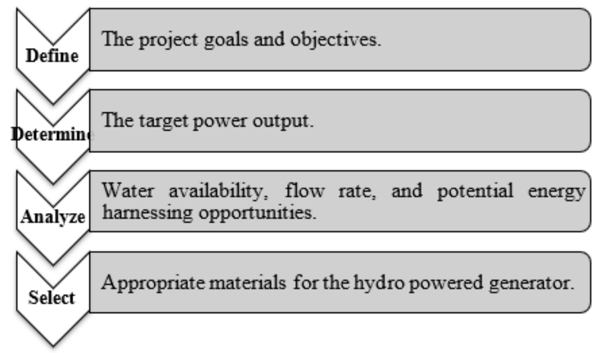
1.8 SCOPE AND LIMITATIONS

The primary focus was on designing and constructing a miniature prototype of a hydro-powered generator, without delving deeply into material selection or complex design aspects. Market factors related to hydropower technology and electric energy, such as building costs and affordability, were not addressed. The study assumes the availability of necessary materials, components, and technologies, without considering implementation and maintenance costs. It only accounted for a steady flow of water, and any constraints in obtaining these resources could impact the project's feasibility and implementation. Despite efforts to minimize environmental impact, some disruption to local ecosystems during the system's installation and operation may still occur.

The study is centered on Harnessing Renewable Energy through hydro powered generator in reservoirs that Sitio Madalumdum, San Pedro, Sasmuan, Pampanga can benefit from. The prototype was produced outside the study location, Sitio Madalumdum, to facilitate the production process and ensure convenience for the researcher. All necessary data were gathered from the Barangay Hall of San Pedro, Sasmuan, and the PELCO II Main Office.

A prototype of the hydro-powered generator was constructed to demonstrate the design's mechanism. This prototype was also utilized for data collection.

1.9 CONCEPTUAL FRAMEWORK



Definition of Terms

Sustainable - means able to continue over a period of time. It also has little or no damage to the environment and therefore able to continue for a long time.

Hydropower - A dam or other diversion structure is used to change the natural flow of a river or other body of water in order to produce electricity, a renewable energy source known as hydropower or hydroelectric power.

Power - In science and engineering, power is the rate at which work is completed or energy is delivered in a given amount of time. It is expressed as the work (W) or energy transferred (t) divided by the time interval (W/t).

Generator - a device that transforms energy from one source—mechanical into electrical, as in a dynamo, or electrical into sound, as in an acoustic generator—into another.

2. METHOLOLOGY

2.1 RESEARCH DESIGN

This study uses an Experimental quantitative research design which, according to doctoral journey utilizes the scientific approach. It establishes procedures that allow the researcher to test a hypothesis and to systematically and scientifically study causal relationships among variables.

Experimental research uses the scientific method to find preferable ways of accomplishing a task for providing a service. In this case, experimental fits in with this research because it demonstrates how data is gathered and to make a correct assessment of results. This method is used to assess the design of this project since the researcher focuses on designing mechanisms.

2.2 RESEARCH LOCALE

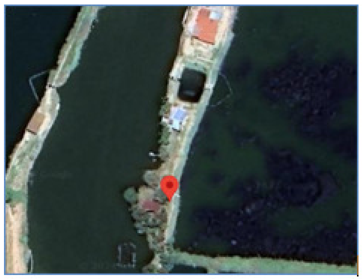


Figure 2.1 Map of Sitio Madalumdum San Pedro, Sasmuan, Pampanga

In this study, the researcher designed a pico-hydropower system to provide electricity to Sitio Madalumdum, San Pedro, Sasmuan, Pampanga, where there is currently no access to electricity.

Sitio Madalumdum, situated in San Pedro, Sasmuan, Pampanga, is a community that would benefit from upgraded infrastructure to provide lighting for homes, thereby improving safety and security, particularly at night. The area's closeness to a water source makes it an ideal location for a hydropower generator.

2.3 METHOGOLOGICAL FRAMEWORK

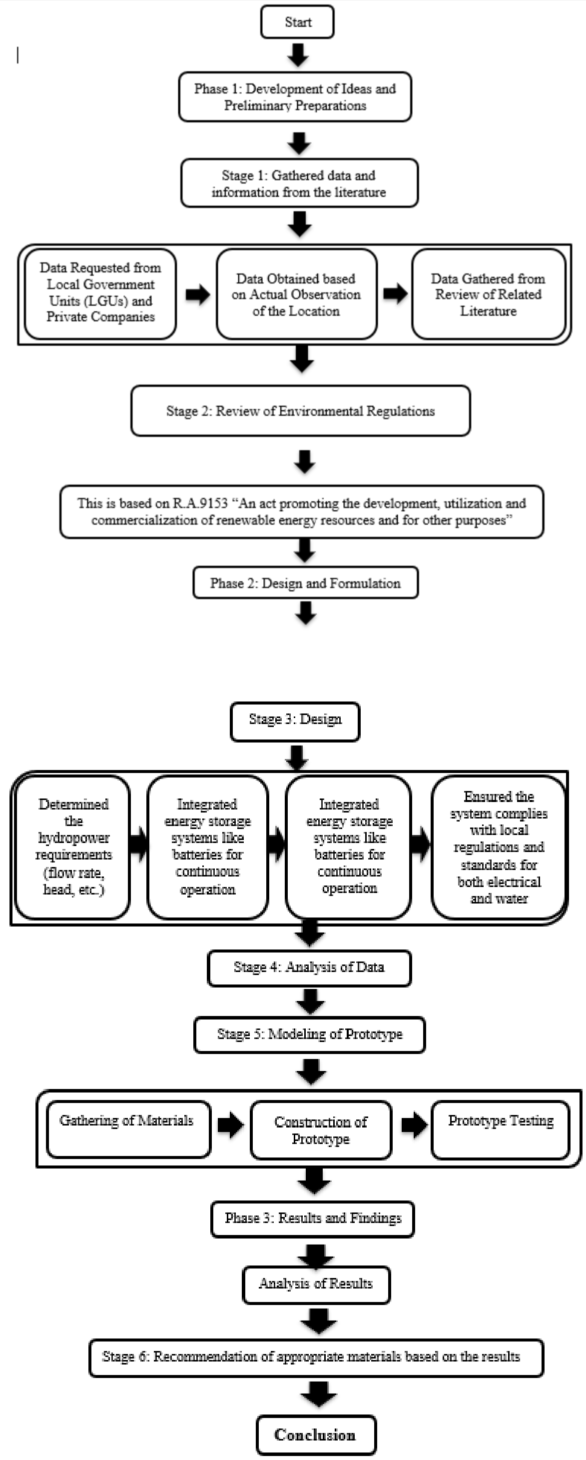


Figure 2.2. Methodological Framework

2.4 PHASE 1: Development of Ideas and Preliminary Preparations

Prior to Designing the mechanism of the hydropower, researchers gathered the necessary data to be used. Phase 1 is divided into 3 stages which are:

- **Stage 1**: Gathered data and information from the literature review
  - The researchers gathered data and review related studies and related literature. This includes:
    1. Data Requested from Local Government Units (LGUs) and Private Companies
    2. Data Obtained based on Actual Observation of the Location
    3. Data Gathered from Review of Related Literature
- **Stage 2:** Review of Environmental Regulations
  - This is based on R.A.9153 "An act promoting the development, utilization andcommercialization of renewable energy resources and for other purposes.

2.5 PHASE 2: Design and Formulation

- **Stage 3:** Design

- Stage 4: Analysis of Data gathered
  - Analyzed the variability and the required water flow rates. This information is essential for achieving the desired power output.

Below are some key calculations and formulas that may be relevant:

- **Equation 2**

  P = **Voltage (V) x Amperes (I)**

- **Equation 3**

  Power – can generate of the mechanism = **γQE**

  Where:

  γ – Unit weight of water

  Q – Discharge flow

  E- Energy Head

- **Equation 4**

  E = $V^2/2g + P/\gamma + z$

- **Equation 5**

  Q = AV

- **Stage 5:**Modeling of Prototype

The researchers developed a prototype model of the hydro powered generator this include components such as the energy storage.

- Gathering of Materials
- Construction of Prototype
- Prototype Testing

2.6 PHASE 3: Results and Findings

- **Stage 6:** Recommendation of appropriate materials based on the results

The researchers recommended appropriate materials that will be used in the mechanism based on the results of all the data gathered.

- Metal or Steel Waterwheel
- Steel axle
- Gears
- Buttress Dams
- Permanent Magnet Synchronous Generator
- Thrust Bearings and Plain Bearings
- Lithium-ion Battery

2.7 ETHICAL CONSIDERATION

This research project focuses on creating a hydro powered generator to produce electricity in Sitio Madalumdum San Pedro, Sasmuan, Pampanga. To achieve this, the researchers intend to adhere to the established guidelines and protocols employed by professionals in the field. This commitment is made with the overarching goal of ensuring the safety of machinery, not only in its operational capacity but also with due consideration for the well-being and security of the surrounding community.

2.8 DATA COLLECTION

The study collected essential information for the thesis development process. The data were separated into three categories: Data Requested from Local Government Units (LGUs), Data Obtained Based on Actual Observation of the Study Area, and Data Obtained from the Review of Related Literature.

2.8.1 List of Data

2.8.1.1 Data Obtained from Local GovernmentUnits (LGUs) and Private Companies

The researchers obtained these data from PELCO Main Office in Guagua, Pampanga

- Unserved Sitio at Sasmuan – It was used to determine the suitable location for our research.
- Total Households – It was used to describe the demographic situation of Sitio Madalumdum, San Pedro, Sasmuan, Pampanga.

The researchers gathered these data directly from the Barangay Hall of San Pedro, Sasmuan, Pampanga.

- Estimated width and depth of the river along Sitio Madalumdum – it was used to determine the flow rate.
- Elevation of Sitio Madalumdum

2.8.1.2 Data Obtained based on Actual Observation of the Study Area

The researchers visited the location of the study, Sitio Madalumdum San Pedro, Sasmuan, Pampanga, and conducted the float method to get the flow rate.

2.8.1.3 Data Gathered from Internet or Online Sources

These data were collected from reliable online publishers and secondary sources. They were utilized as supplementary information in the design and creation of the hydro-powered generator.

- Related Literature - This data was utilized to identify the necessary quantitative parameters of the hydropower machine. Specifically, it was employed to ascertain the required standard hydraulic head, flow rate, and physical dimensions, which were essential for the overall design.

2.9 DATA ANALYSIS AND EVALUATION

2.9.1 Design and Modeling

This section is divided into two parts: Design and Formulation. In the Design part, all relevant principles and concepts were identified and discussed. The Formulation part applied these principles to develop a practical solution.

2.9.1.1 Design

A. Waterwheel Concept

A waterwheel is a simple turbine device with buckets, paddles or blades that is rotated by moving water, converting the kinetic energy of water into mechanical movement. In Bellis's study, in typical installations, waterwheels are placed vertically above a water reservoir, with their axles oriented horizontally. This axle serves to transmit the energy derived from the descending water to either a drive belt or a set of gears, which in turn powers various machinery. Such waterwheels rely on access to flowing or cascading water, which may come from streams or rivers [25].

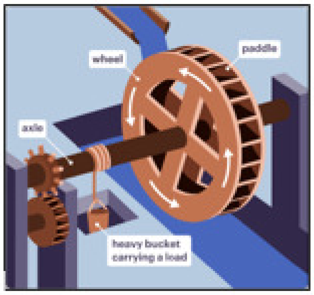


Figure 2.3. Waterwheel Concept

B. Geometric Dimension

Calculating the geometric dimensions of a hydro powered generator within the context waterwheel concept involves assessing various factors such as the size of the waterwheel, the flow rate of water, the head (height) of water available, and the desired power output.

C. General Design

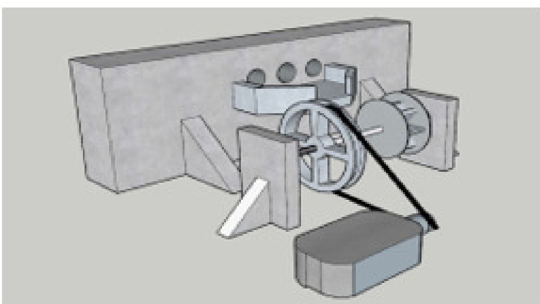


Figure 2.4. General Design of the Hydro Powered Generator

Figure 2.5. General Design of the Hydro Powered Generator Prototype

The overall design of the hydro-powered generator prototype was separated into the following components.

C.1 Dam

The researcher used a 2 cm plyboard for the dam. As shown in Figure 1.8, the dam has two supports which acts like a buttress. According to the U.S. Department of Energy [5], Buttresses are triangular concrete walls that is used to provide additional strength and stability to structures.

C.2 Waterwheel

The researcher utilized two compact discs (CD) and popsicle sticks with bottle caps that served as buckets to make the breastshot waterwheel. Breastshot waterwheel is another vertically-mounted waterwheel design where the water enters the buckets about half way up at axle height, or just above it, and then flows out at the bottom in the direction of the wheel's rotation. According to B.,H.,W.,Agus et. al [26], the breastshot waterwheel may be used as an independent power plant in remote areas due to its efficiency. In addition, the study results reveal that this turbine is not significantly affected by the garbage (household waste) in the water.

C.3 Pulley and Belt System

Pulley and belt system was utilized to transfer the rotation from the big wheel to the generator. Jaber and Ali describe a pulley and belt system as a rotating mechanism that transfers loads between pulleys using a belt. This system typically includes two or more pulleys, each pair connected by a belt [27].

In this study, the researcher will be using a 9.5 inches diameter driving pulley and a 0.3 inches diameter driven pulley. The two pulleys were interconnected using a rubber band acting as the Belt. Thus, it produces a ratio of 1:0.08 for the rpm generation.

C.4 Generator-Motor

A DC motor generator was positioned at the other end of the pulley and belt system. It converted the mechanical energy from the waterwheel into electricity. The generator's operation was based on the rotational speed of the turbine.

In this study, the researchers used a 5V motor generator with a speed rated at 2500 rpm.

C.5 Circuit board

The study used a Charging Circuit Board for the conversion of mechanical energy into electricity. The charging circuit board takes the electrical output from the generator and converts it into a usable form. This usually involves converting the alternating current (AC) produced by the generator into direct current (DC) that can be used to charge batteries or power devices.

C.7 Connected lights

Light-emitting diode (LED) light bulbs rated 0.5 Watts were utilized in this study. These bulbs are energy-efficient, have low power consumption, and are often rechargeable. They can be used for camping, emergency lighting, or as a portable light source in different settings.

D. Hydraulic Concepts

The following hydraulic principles were crucial for the results and conclusions of this study.

1. Revolution Per Minute (rpm)

Revolutions per minute (rpm) is a unit that measures rotational speed (N), indicating the number of turns or cycles an object completes in one minute.

$$rpm = \frac{revolution}{time\ (in\ minute)}$$

When creating a design, rotational speed (N) is a crucial element that must be taken into power plant. Quaranta states that rotational speed is one of the main key ideas to take into account in order to establish the necessary good working conditions and effectiveness of the hydropower plant's design. The faster the rate of rotation, which indicates the hydropower facility generates more power at higher revolution rates [4].

1.Flow Rate

Flow rate (Q) is defined as the volume of water passing a point per unit of time, typically measured in cubic feet per second (cfs) or cubic meters per second (cms). The float method was employed to measure the river's average volumetric flow rate.

2. Theoretical Power considering flow rate and hydraulic head

Theoretical Power (*PT*), also referred to as hydraulic power, is the predicted electrical power generated by a hydropower system, based on the flow rate and hydraulic head derived from gravitational energy. According to Pasalli and Rehiara [28], the formula for calculating the theoretical power output of a hydropower system is:

$$PT = \gamma QE$$

wherein;
PT - theoretical power generated (Watts)
γ – unit weight of water
Q – discharge
E – Head

2.9.1.2 Modeling of Prototype

The following were the steps for the modeling of the hydro powered generator.

1. Gathering of Materials

The materials needed to construct the designed hydro-powered generator were identified and gathered before building the model. A 5-volt was used as the DC motor. For the lights, the researchers used LED Lights. For the dam, the researchers used a 2cm scrap plyboard. A circuit board was utilized to convert mechanical power to electricity.

2. Construction of the prototype

The researchers started by preparing the materials required for the study, following the finalized general design. To generate a flow rate, a 24-inch hose with a 0.5-inch diameter was connected to a 1.5-liter bottle cut in half. The water wheel consisted of two compact discs (CDs) with popsicle sticks attached, and bottle caps serving as buckets. For the dam, the 2 cm plyboard was cut into 12x16.5 inches. 0.7-inch 3 orifices were made on the plyboard. 4.5x5 inches spillway was attached right below the orifices.

The water wheel and driver pulley are connected by an aluminum rod that served as an axle which is 15 cm. The rod is attached to a bearing making it rotate smoothly. The driver pulley which is 3.9 inches was connected directly to the 5V Direct Current (DC) Motor by pulley and belt system.

In this study, the generator consists of DC motor and the circuit board, the circuit board was connected to the DC Motor using an electrical wire. Lastly the LED light is connected to the circuit board.

After preparing the materials, the researchers assembled all the materials based on the design.

3. RESULTS AND DISCUSSION

3.1 Actual Hydropower generator

The following calculations outline the power output of the hydroelectric generator, taking into account its actual dimensions.

3.1.1 Flow Rate Measurement

Investigating the flow dynamics of rivers is crucial for various environmental and engineering studies. To assess the flowrate of the river in Sitio Madalumdum, San Pedro, Sasmuan, Pampanga, researchers employed the Float Method. This methodology involves estimating distances along the river, utilizing a floating material to track the time it takes to traverse from one designated point to another, and subsequently calculating the average time. Through this process, velocity is determined by dividing the average time by the distance between the two points. Moreover, to quantify the flowrate accurately, the researchers gathered data on the channel's width and depth to calculate its cross-sectional area. This area, when multiplied by the velocity, provides valuable insights into the river's flow dynamics, contributing significantly to the comprehensive understanding essential for environmental management and engineering applications.

Table 3.1.1 Recorded Data Using Float Method and Stopwatch Method

Trial	Distance (meter)	Time (second)
1	5.12	7.35
2	5.12	7.85
3	5.12	7.25

As shown in Table 3.1.1, the study conducted three trials to determine the average time required for a floating material to travel a distance of 5.12 meters. In the process, trial 1 recorded a time of 7.35 seconds, trial 2 recorded 7.85 seconds, and trial 3 recorded 7.25 seconds. The average time for the floating material to travel was calculated by dividing the total time by the number of trials, resulting in an average of 7.48 seconds. To determine the water velocity, the distance in meters was divided by the average time in seconds, yielding a velocity of 0.684 m/s.

The flow rate represents the volume of water passing through a specific point per unit of time. Through the application of the flow rate formula and based on the estimated width of the river along Sitio Madalumdum which is 15 meters and depth of 3.05 meters for the hydro-powered generator, the determined flow rate is 31.29 m3/s.

3.1.2 Theoretical Power Calculation and Analysis

The theoretical power output of a hydro-powered generator can be determined by considering both the head and the flow rate of the water.

Power is the amount of work done in a given amount of time. The power (Watt) of a fluid with unit weight γ (N/m³) and total energy E (m) flowing at a pace of Q (m³/sec) may be found using the following equation: Power = γQE [29].

Applying the formula of discharge, the discharge of the river is 31.29 m3/s. The discharge is then divided to three for the three-circular orifice. We used the target power which is 30 Kw/day as P and equated it to the unit weight of water, discharge flow and velocity head to get the E. The velocity head is 0.293m.

Applying the Bernoulli's equation to get the velocity, the velocity is 2.40m/s. After getting the velocity, the researchers got the diameter using continuity equation, applying the equation we got 2.5m as the diameter. Using the diameter, we got to solve the new discharge of 11.78 m3/s per circular orifice. Applying the formula of the Theoretical Power, we got 33.86 KW or 45.39hp.

3.2 PROTOTYPE CALCULATIONS

3.2.1 Flow Rate Measurement of the Prototype

After building the waterwheel system of the designed hydro powered generator, the researchers started to determine the flowrate of the water on the system using the bottle and stopwatch method. A 1.5-liter plastic bottle was used un this study for the bottle and stopwatch method, and measured the time it takes to fill the container.

Table 3.2.1 Recorded Data Using Bottle and Stopwatch Method

Trial	Volume (liter)	Time (seconds)
1	1.5	11.43
2	1.5	11.46
3	1.5	11.29

As shown in Table 3.2.1, the study conducted three trials to ascertain the time needed to fill a 1.5-liter plastic container. In this process, trial 1 recorded a time of 11.43 seconds, trial 2 recorded 11.46 seconds, and trial 3 recorded 11.29 seconds. Calculating the average time across the three consecutive trials involved dividing the total time by the number of trials, resulting in an average fill time of 11.39 seconds for the 1.5-liter plastic container.

Applying the formula of the flow rate, the researchers obtained a flowrate of 0.0001317 m3/s.

3.2.2 Flow Velocity and Rotational Speed Calculation

Flow velocity refers to the distance traveled by water per unit of time, and it can be determined by considering the connection between flow velocity and flow rate. The study used a hose with a 0.0127m diameter. Applying the formula of flow velocity, which is equal to the flow rate and cross-sectional area quotient, the study obtained a flow velocity equal to 62.382 m/min or 1.0397 m/s.

For the waterwheel, the study used a 9.5 inches diameter wheel. Applying the formula of rotational speed, the study obtained a rotational speed of 82.05 rpm, say 83 rpm. The study used pulley and belt systems to increase the rotational speed. The waterwheel and the driving pulley are similar in size therefore they produce the same rpm.

Table 3.2.2 Computation for Pulley Diameter and Rotational Speed

Pulley	Diameter (inches)	Rotational Speed (RPM)
Driving	9.5	83
Driven	0.3	1033

The driven pulley is connected to a generator. Utilizing the rotation from the driven pulley, the study used a 5-V dc motor as generator, which can cater to rotational speeds from 2500 – 3000 rpm.

3.2.3 Theoretical Power of The Prototype based on Flowrate

Theoretical power can be determined considering the flow rate by multiplying the unit weight of water, gravitational acceleration, flowrate and velocity head of the system. The study used a 0.0551 m velocity head. Applying the formula, the theoretical power of the designed hydro powered generator is 0.0712W

3.3 APPLYING THE EFFICIENCY FACTOR TO THE THEORETICAL POWER

According to Bukar M. Et. al. [30], One of the most important factors in determining the effectiveness of pico-hydropower systems is their efficiency. Studies have revealed that the normal range of pico-hydropower's standard efficiency is between 60% and 80%.

The obtained theoretical power is 0.0712W. Applying the efficiency formula, the minimum efficient power is 0.0427W, and the maximum efficient power is 0.0570W.

3.4 PROTOTYPE TESTING

Following the completion of constructing the entire hydro-powered generator prototype design, the researchers-initiated prototype testing.

The prototype successfully lit a 0.5 watts LED bulb using the head pressure to rotate the improvised waterwheel. Having a head of 0.0551m and 0.5 inch as the diameter of pipe, the mechanism produces a discharge flow of 0.0001317 cms. With the assistance of pulley system, the waterwheel is simultaneously rotating with the big wheel or the driver pulley that is connected with a rubber band to the smaller wheel that serves as the driven pulley, the DC motor starts to rotate and generates electricity to light up the LED bulb.

Table 3.4. Actual Generated Voltage of the Prototype

Trial	Recorded Voltage (V)
1	1.007
2	1.068
3	1.028

As shown in the table 3.3, the researchers performed three trials to obtain the voltage of the designed prototype. Upon the process, trial 1 got 1.007V, trial 2 got 1.068V and trial 3 got 1.028V. In getting the average voltage of the three trials, simply get the sum and divide on the number of trials, the average actual voltage is 1.034V.

According to the study of Luckhurst P. [31], Knowing how voltage, current, and power are related is necessary to convert between volts and watts. The formula for converting volts to watts in direct current (DC) circuits is P (W) = V (V) × I (A), The average ampere used for this study is 0.05 amperes. Applying the formula, the actual generated power is 0.0517W.

3.5 COMPARISON AND ANALYSIS

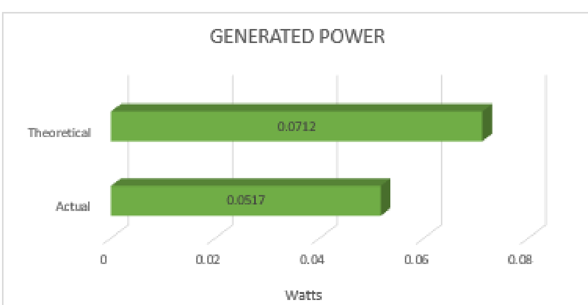


Figure 3.1. Comparison between Actual and Theoretical Generated Power

As shown in Figure 1.8, the electrical power generated is less than the theoretical power. The generated electrical power is 0.0517W, whereas the theoretical power is 0.0712W. Through analysis, it's observed that the theoretical power exceeds the actual generated power.

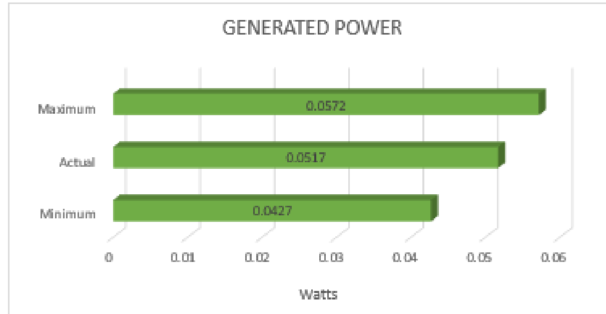


Figure 3.2. Comparison between Actual and Efficient Theoretical Power

The study determined a theoretically efficient power range from 0.0427W to 0.0572W. The objective was to generate electricity that surpasses the minimum threshold and approaches the maximum to assess the design's efficiency. Figure 3.3 displays the actual generated power of 0.0517W, falling within this calculated efficient power range. Consequently, the study concludes that the design operates at 72.61% efficiency.

3.6 CHOOSING APPROPRIATE MATERIALS

Based on the results of the prototype, the researchers chose more appropriate materials to be used in the actual design.

- **Metal or Steel Waterwheel**

  The most efficient materials for a waterwheel used in a hydropower generator are steel and metal. The search results indicate that modern waterwheels are often made from steel, which has promising effects on the environment compared to older wooden designs [32].
- **Steel Axle**

  According to Jeanty T. Et. Al. [33], Because of its strength and stiffness, which are essential for bearing the weight of the wheel and guaranteeing smooth operation, the steel axle is the chosen material for waterwheels. A steel axle resists deflection since it is strong and solid, unlike wooden axles that could flex or bend when driven. This quality is necessary to keep the waterwheel's structure intact and enable it to run smoothly without experiencing problems with deformation or instability.

- **Gears**

Gears are usually thought to be superior than belts. Compared to belts, gears offer a more dependable and efficient power transfer system [32].

- **Buttress Dam**

Buttress dams are regarded as a solid basis for the production of hydropower since they have a number of important benefits. Buttress dams are a more affordable alternative for hydropower projects since they require less concrete than gravity dams [34].

- **Permanent Magnet Synchronous Generator (PMSG)**

The Permanent Magnet Synchronous Generator (PMSG) is preferred because of its many benefits. Because of their high-power density, dependability, and efficiency, PMSGs are suited for a range of renewable energy uses, including hydropower. Compared to conventional generators, these generators have better performance, less maintenance needs, and better control capabilities. In addition, PMSGs are renowned for their ease of use, small size, and capacity for variable speed operation, all of which maximize the effective conversion of water's kinetic energy into electrical power [35].

4. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

4.1 CONCLUSION

The hydro powered generator is a technology innovation that can positively provide electricity to unserved areas for basic household use. The design in Figure 1.8 was used to construct the prototype. The hydro powered generator prototype worked and produced electricity of 0.0517W or 1.03V and can light a 0.5W LED light.

The power plant employing the prototype is capable of lighting a 0.5W LED light using the 0.0517W of generated electrical power. This suggests that the prototype's ability to generate electricity presents a promising opportunity to address the electricity shortage in Sitio Madalumdum.

The sustainability of the design was based on the prototype. With the continuous discharge of water, the mechanism continues to light up the 0.5 Watts LED light. Therefore, this validates that man power or any kind of external energy input is not needed for the prototype to operate continually. The actual design is expected to produce 33859.61W or 33.86kW.

The designed hydropower generator prototype yielded an actual power generation of 0.0517W, while the calculated minimum and maximum efficient powers were 0.0427W and 0.0570W, respectively. Analyzing this data reveals that the actual power output exceeds the minimum and falls below the maximum efficient power, indicating that the design effectively generated electricity within the range of average efficient power. Thus, the study concludes that the hydropower generator design is efficient.

4.2 RECOMMENDATION

The recommendations section in a research study is significant as it offers further suggestions and alternative solutions for addressing the research problem. In this study, the recommendations are categorized into two parts: recommendations for enhancing the prototype and recommendations for enhancing the study.

Recommendations for enhancing the prototype stem from the challenges encountered during its construction.

First, source of water is very essential for the discharge flow for the reason that it will be the driver of the waterwheel. Continuous source of water will provide a consistent flow that is equal to the rotation per minute of the waterwheel for the uninterrupted production of electricity. However, if the source is not available gate, is another option. By applying gates to the orifices, required water level to produce the appropriate discharge flow can be accumulated.

Exploring various technologies to achieve increased rotational speed for the mechanical component, such as employing a pulley and belt system as done in the study, suggests considering alternatives like gears for improved performance.

The study utilized a 5V DC motor generator with a speed of 2500 rpm to power a 0.5W LED light, as indicated by the findings. The researchers suggest exploring a low rpm but higher voltage DC motor for future studies to power LED lights greater than 0.5W. However, they note that such generators can be costly and challenging to procure due to limited availability.

The prototype only used glue stick as an adhesive. Thus, this affects the stability of the prototype. The study recommends using different methods to connect the materials together to increase durability.

Lastly, use different appropriate materials and mechanical components because the researchers only used scrap and affordable materials.

The recommendation to enhance the study is based on the identified limitations of the research.

This study only provided a design that is suitable only for the available materials. Despite having the capability of producing energy, the scaling of this mechanism is not included. Future researchers ought to conduct investigations to determine the correlation between scaling the design and the resulting power output of the mechanism. Additionally, the complexity of the design necessitates examination. This entails consideration of specific materials and precise dimensions.

The hydro powered generator is a large project with high-priced materials that will incur significant expenses. According to Hanan, A. [36], numerous factors can affect a hydropower generator's cost. The infrastructure needed to capture hydroelectric energy, such as dams, reservoirs, and turbines, which demand large building expenditures, is one major reason driving up the cost of hydropower generators.

Another recommendation is the consideration of physical and mechanical properties of soil and hydraulic concepts of the location where the project will be construct. This study only considered the estimated data about the location from local government of barangay San Pedro, Sasmuan, Pampanga. According to Postacchini M. (2020), concepts from hydraulics and soil mechanics are intimately related when discussing the production of hydropower. The hydraulic turbines of hydropower facilities use the flow of water to produce energy. The physical qualities and flow characteristics of the water affect the performance and efficiency of these turbines, and these factors are determined by the laws of soil and fluid mechanics.

In this study, the researchers only used the prototype's performance for the credibility of the sustainability and efficiency of the design. This also goes for the comparison of actual power output and theoretical power output. Researchers recommend that performing other methods will increase the credibility of the design. Future researchers are recommended to also use software to provide simulation models for the mechanism.

Lastly, the researchers recommend expanding the scope of the study and not limiting the power output for a small community. Extending the scope for the project can also result in a substantial power output, which is capable of supporting not just the basic needs for electricity.

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