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Development of 150 Watts, 12V Hydraulic Wheel DC Generator for a Farm at Brgy. Ligaya, Pulungmasle, Guagua, Pampanga

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INTRODUCTION

In times of growing energy demand, twiddling natural resources and the climate change debate, the development of new technology for sustainable power generation is becoming ever more important. Experts have been pioneering the generation of wind energy from the beginning. Now, it is time to turn the successful and sustainable concept upside down and take it underwater when the tides and waves provide a great supply of clean energy. The water and advance technology guarantee a much more presage output than other renewable energy. Hydropower is a promising contributor in a clean and efficient energy makes for the future turning the water motion in power generation.

Hydroelectric energy is the number one renewable source for electricity generation across the board, girding 71%

of all renewables. Up to 1,064 GW of installed capacity in 2016, it brings about 16.4% of the world's electricity. Hydroelectric power is the most adaptable and coherent of all the renewable resources, the ability of meeting base load electricity requirements. There are many opportunities for hydroelectric development and although there is no open agreement, assessments denote the availability of almost 10,000 TWh annually of unused hydroelectric energy potential in the world (World Energy Council, 2016).

Hydroelectricity is derived from the energy running or moving water, which may be yoked for beneficial purposes. Since earliest times, hydroelectric power from many varieties of watermills has been used as a renewable source of energy for irrigation and the process of numerous machine-driven devices, such as sawmills, textile mills, trip mallets, mooring cranes, domestic lifts, and metal mills (Department of Energy, 2017).

Southeast Asia's first marine tidal power plant will start to be erected in the Philippines on mid-2017, as proceeds it paces to green energy. A resident firm in Asia arose with an impression of exploiting those tidal waves to yield energy. This was such a noble knowledge that can enhance more foundations of dynamism, apart from the current power plants in the Asia (Philippine News, 2017).

Devices, which produce kinetic energy, are significant in promoting renewable energy such as hydroelectric energy. A water pump is a device that moves water by mechanical action. Seeing the water flow and knowing about hydroelectric energy as a source of energy, the researchers get into the idea of making the water pump as a source of moving energy producing electricity that can supply lighting loads to promote security and convenient maintenance.

It is a requirement for farmers to stay in the fields for the maintenance of the land and time to time regulation of fishponds. Cultivator's usually install water pump system for sustaining enough supply of water. Building a small home for the pump is the farmer's way of protecting it from theft. This also serves as the farmer's lodge when the cultivators want to take a break from the field and at night when checking the performance of the pump. In line with this, farmers are obliged to bring flashlight or emergency lights as source of luminescence. Having a system that can provide respondents with a source of electricity to supply the lightings needed will be a great help in maintaining fields and ponds.

The main reason behind the latest peak of hydroelectric energy capacity is due to enhanced technology. Numerous components of a hydroelectric technology must be taken into account. Innovative developments in the structure using enhanced, lightweight materials, and improved design techniques have permitted today's turbine to hit better water movements for reduced cost. It is vital to continue refining the design of the hydroelectric turbine in order to produce better energy and improve its cost.

As energy requirements are continuously varying, the operational elements linked with the new energy foundations need to be established. An understanding of all the energy sources, mechanical, and basic components associated to the design, construction, and process of hydroelectric generators must be assessed to develop an idea for the design and administration of the project. The whole concept of the study came up to upgrade the knowledge of the people about using renewable source of energy effectively for everyday living.

In most farms with water pump system installed, lighting issue is one of the primary problems of farmers. The researchers have seen the activity of the water as one of the key variable. Since water is nearly incompressible, if a certain run is required to travel through a reduced cross section of channel, it can only do so by rolling quicker. As a jet of water driven by the pump pressure leaves the pipe and drops in the irrigation tank, it creates kinetic energy. Specifically, the researchers will develop a hydraulic wheel generator to be installed in a water pump system to produce sufficient electricity to sustain the power requirement of the loads.

The primary objective of the study is to make an energy-harvesting device from water movements as a source of electricity. The researchers aim to develop a hydraulic wheel generator that can regulate the water pressure and flow during the pump operation. To generate electrical power that will supply loads such as lighting loads and batteries for flashlights. This study will mainly focus on the application of the hydraulic wheel in a water pump system at a specific site in Barangay Pulungmasle, Guagua, Pampanga. Hydroelectric energy as a source of energy is already known and already used worldwide. The system is primarily intended to operate lighting loads and batteries for charging purposes. The researchers aim only on transforming the traditional water pump operation into useful energy efficient pump system. This proposal concerns delicately on the mechanical side and mainly on the electrical side of the hydraulic wheel system.

The hypothesis of the study involves the mechanical efficiency and the electrical efficiency of the system. The null hypothesis is that there is no significant correlation between the mechanical and electrical efficiency of the system. The alternative hypothesis is that there is a significant correlation between the mechanical and electrical efficiency of the system.

The security of the water pump at night will be employed with the help of renewable power, supplying the lighting loads. Proper illumination in the small home of the water pump is a great support in sustaining the safety of the equipment as well as the maintenance of the fields and ponds. Researchers can provide the people with the knowledge to make use of the renewables as a source of electricity.

This study delivers educational significance related to Electrical Engineering. New knowledge is required to the expansion of the study. In creating such reliable project, one needs some advanced analytical skills. This paper will also serve as a reference to the future researchers who will conduct the same study regarding hydroelectric energy and hydro turbine designs.

The current state of expertise makes hydroelectric energy a lasting asset opportunity with possibly significant but highly uncertain returns. In the time being, the early phase of the technology and great monitoring costs linked with extensive approving requirements and authorizing reservations are likely to remain bestowing major cost-effective hurdles to commercialization of the technology. In the contrary, these developing technologies have the probable to offer important quantities of affordable electricity with low ecological influence given suitable care in setting, placement, and procedure.

The consumption of waterpower ages thousands of years ago to the water rolls of Prehistoric Greece, which recycled the energy in dwindling water to produce power to drudge wheat. At present, the chance to progress a new generation of waterpower is one of today's innovations that will bind the copious energy of oceans and streams. Hydroelectric technologies harvest renewable electricity by hitching the kinetic energy of a bulk of water, the energy that outcome from its motion.

Recently, small, entrepreneurial companies dominate the hydroelectric energy conversion industry. A handful of large engineering and manufacturing firms have entered the field, primarily by buying designs near commercialization. Upon completing this project, it will have a great impact in the modern technology especially in Philippine technology. These emerging technologies have the potential to provide essential amount of affordable electricity.

Many have conducted a research worldwide to improve and make use of the world's renewable energy. Some are already applied in different places and widely used for an upgraded way of living but still these researches are not enough to satisfy the needs of humanity. According to a review of wave energy converter technology (2009), presents the existing standing of wave energy converter (WEC) technology, the diverse device kinds are recognized and assessed. The organizations and establishments tangled in WEC growth, as well as cooperative wave energy schemes, are also acknowledged. The probable power take-off (PTO) structures are evaluated and categorized as hydraulic, linear electrical generator, or turbine founded. A hydraulic PTO scheme is principally well suitable to captivating energy from a great fo rce, slow oscillatory indication and can enable the alteration of responding motion to rotary motion to drive a generator. There are, however, several design encounters such as proficiency and consistency. A linear electrical generator delivers an alternate option, but the technology is less established. The dynamic control of a WEC can considerably upturn its efficiency, and hence cost efficacy. This research is presently ongoing with latching control being emphasized as a promising, simple technique of efficiently mining energy (Drew, Plummer, & Sahinkaya, 2009). On the other hand, in streak with the study of energy harvesting in 2010, deals with ocean wave energy reaping in which the kinetic and potential energy confined in the natural fluctuations of ocean waves are transformed into electrical power. Near shore and offshore methods along with necessary absorber, turbine, and generator categories are deliberated. Furthermore, power automated borders for grid assembly states are expounded (Khaligh & Onar, 2010).

A water turbine wheel is a device for changing the energy of rolling or falling water into beneficial forms of power, often in a watermill. A turbine wheel comprises of a wheel (typically made from wood or metal), with a number of blades or buckets organized on the outside rim making the driving surface. Most commonly, the wheel is attach perpendicularly on a horizontal hinge, but can also be fixed horizontally on an upright shaft. Vertical wheels can diffuse power either via the axle or through a ring gear and usually drive belts or gears; horizontal wheels generally straight drive the load. Water wheels were still in viable use well into the 20th century but are no longer in frequent use. A passage for the water rolling to or from a water wheel is called a millrace. The race carrying water from the millpond to the water wheel is a headrace; the one bringing water after it has left the wheel is normally denoted to as a tailrace (Thomson, 2009). Moreover, water wheels originate in two simple designs; a horizontal wheel with a vertical axle and a vertical wheel with a horizontal axle. The last can be divided according to some place the water hits the wheel into back shot (pitch-back), overshot, breast shot, undershot, and stream-wheels. The word undershot can discuss to any wheel wherein the water permits under the wheel but it usually suggests that the water entry is low on the wheel (Power in the landscape, 2017).

The researchers were able to gather a number of information which has the same matter that mainly focused on hydro energy as a source of electricity. Hydroelectric energy is other form of renewable energy that can be recycled as an alternative to fossil fuels – limited resources that discharge damaging carbon secretions into the air when yoked for energy. As water move through, it generates kinetic energy. This undertaking can be used to power turbines, which, in turn, produce energy that can be rehabilitated into electricity. There are also numerous methods of harnessing hydroelectric energy that use the wave of the water to turn generators.

Stream wheels are inexpensive and simpler to construct, and have less of an ecological effect, than other form of wheel.

Some drawbacks are its low efficiency, which means that it produces a small amount of power and can only be used where the flow rate is adequate. An undershot wheel is a steeply attached water wheel with a horizontal pin that is revolved by the water from a low channel arresting the wheel in the bottom area. Most of the energy increase is from the drive of the water and moderately little from the head. It is comparable in action and design to stream wheels. Breast shot wheels are less efficient than overshot and back shot wheels but it can hold great flow rates and subsequently high power. These are favored for stable, high-volume flows. A back shot wheel has the advantage that the extremity of the wheel is stirring in similar direction as the water in the tailrace which marks it more efficient. It also performs better than an overshot wheel in flood settings when the water level may immerse the bottom of the wheel. It will last to rotate until the water in the wheel bottom upsurges quite high on the wheel. A usual overshot wheel has the water directed to the wheel at the top and marginally beyond the axle. The water gathers in the buckets on that side of the wheel, building it heavier than the other empty side. The weight turns the wheel, and the water flows out into the tail-water when the wheel rotates enough to upturn the buckets.

Most of the related studies, hydroelectric turbines are usually installed in oceans for the continuous availability of ocean water flow. Unlike with this proposal, the researchers decided to install the turbine in a water pump system where there is water movement. Through the previous studies, the researchers decided to design the hydraulic turbine wheel in a unique way wherein the investment will be worked out at its lowest cost. An overshot water wheel design will be used in the project. The Overshot Water Wheel Design is the most corporate type of waterwheel design. The overshot waterwheel is more complex in its assembly and design than the preceding undershot waterwheel as it uses buckets or small sections to both fasten and grip the water. These buckets seal with water flowing in at the top of the wheel. The gravitational weight of the water in the full buckets grounds the wheel to rotate around its central axis as the empty buckets on the other side of the wheel become daintier. This type of water wheel uses gravity to develop output as well as the water itself, thus overshot waterwheels are much more efficient than undershot designs as almost all of the water and its weight is being utilized to harvest output power. However, as before, the water's energy is used only once to rotate the wheel, after which it runs away with the rest of the water.

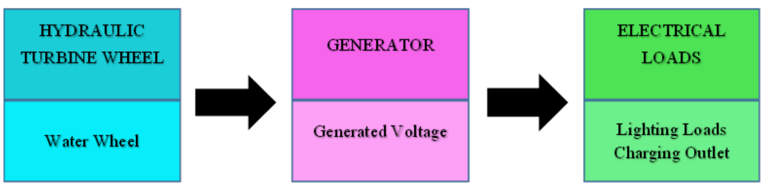

Figure 1. Conceptual Framework Diagram

The quest to turn the motion of the world's waterways into a significant source of energy may still be in its nascent stage, but several waterpower projects are making headway. Whether it operates in lakes, rivers or the oceans, projects attempting to harness the water energy share the same mission: to improve the technology and offer an economical alternative to fossil fuels.

Figure 1 explains the conceptual framework of the study by Input-Process-Output paradigm. In the input phase, hydraulic devices are powered by moving water and are different from traditional hydropower turbines in that devices are placed directly in a river, ocean or tidal current. The system generates power only from the kinetic energy of flowing water. The available hydropower depends on the speed of the water flow. In order to operate, hydroelectric devices require a head and water velocity. The hydro turbine wheel will be developed to produce a maximum amount of electrical power with the kinetic energy of flowing waters. As such, no dams and/or head differential are necessary for the operation of this device; the structure of the water pump remains in its natural state and no high investments in infrastructure are required. Because the amount of kinetic energy (velocity) varies, a greater amount of energy is generated with a higher velocity of water flow. In the process phase, as water flows through a turbine, the kinetic energy of the flowing water is converted into electricity by the generator and therefore will produce power that will be used in supplying the loads as an output.

METHODS

This chapter details out the research methodology for the present study. The purpose of this section is to identify and explore the issue and provide a linear solution in accordance with the curriculum the researchers are undertaking. The researchers will use the exploratory research design. Through this, the team will conduct a survey to familiarize with the basic details, settings, and concerns. The intention of the group is to provide a well-grounded picture of the situation being developed and to determine about whether a study is feasible in the future. A preliminary survey will be performed to generate new ideas and assumptions. It will be an interview for the selected groups of experts in hydroelectric energy and for the farmers experiencing the problem. The researchers will ask broad open-ended questions that are designed to receive large amounts of content, providing the freedom to demonstrate the respondent's knowledge.

The questions are each important to the discussion of how hydroelectric energy technology and the water pump operation works. The knowledge gained by the technology assessment will help create a better understanding about hydroelectric technology and its role in the future of electricity. The process of interviewing for the technology assessment will begin with the experts studying on or conducting hydro energy technologies. Five persons will receive the interview questions prior to the phone/personal interview that will be conducted and will be asked if they are willing to participate. The persons that will participate must be aware that all information provided during the interview will be recorded and then evaluated for this thesis. Because the information would be public, prior to the start of each interview, for any reason, if there were questions, the respondents do not want to answer, the person should decline to answer. The methodology of the technology assessment is straightforward. Questions are designed to assess the overall feasibility of this technology, especially given its site-specific design and operational context and to identify barriers and opportunities related to the further development of hydroelectric systems.

The research framework of the study will be used to shape the whole activity. It will serve as guide through the steps involve within the study.

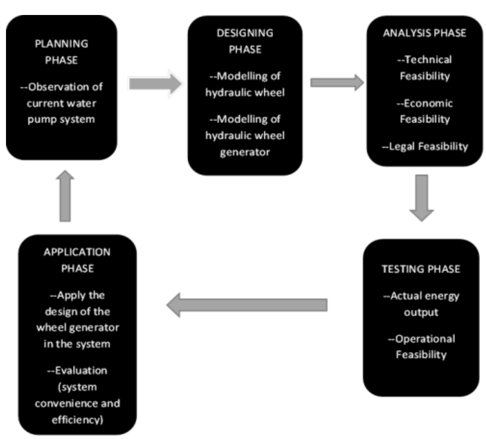

Figure 2. Research Framework Diagram

Figure 2 shows the methodology for the proposed topic in this paper is an approach based on sequential steps, relating to different levels of detail in the information that needs to be gathered.

Phase 1: Planning Phase

The first step aspires to conduct another assessment that will mainly focus on the suitability of the area. The initial site assessment will cover the permission section and the site analysis. Once an interest for constructing a hydro turbine wheel system has been shown, a site must be chosen and evaluated based on the optimal conditions for installing a water wheel, which are outlined in the following sections. These steps are necessary to develop a turbine to produce the maximum profit return to the investor based on the expected value of the system.

Site Analysis

There are several factors that must be considered when choosing an appropriate site for a hydraulic wheelsystem. The factors include:

- Social Constraints

  The use for the electricity must be analyzed and the most economically beneficial option should be chosen. If there are no beneficial options, a different site should be considered.

- Location of the Loads relative to the Hydraulic Wheel Generator

  The distance between the turbine site and the loads is also a factor to be considered. If this distance is too great, it is not practical to install a turbine wheel on the site. This is because the electricity would have to travel such a great distance to be disbursed that it would not be economically beneficial. Since the water pump system where the device will be installed is in the field where the loads are, the distance between the two is applicable in installing such device.

Permission

After these first initial variables are considered, the next factor that should be researched is the community's decision making process. This is important to the turbine wheel process because it is information on the steps that must be taken to obtain project approval. The group will administer a personal interview to the municipal/barangay council of Brgy. Pulungmasle, Guagua, Pampanga to know the town's bylaws governing the hydraulic wheel system approval and installation process. Upon knowing all the rules regarding the the installation of the device, the researchers will submit a barangay permit prior to the beginning of the project.

Phase 2: Designing Phase

The project researchers will develop an overshot turbine wheel system to be installed in the water pump system. The following quantities and units will be gathered during the design phase:

- ŋ = efficiency
- ρ = density of water (1000 kg/m^3)
- A = cross sectional area of the channel (m^2)
- D = diameter of wheel (m)
- P = power (W)
- d = distance (m)
- g = strength of gravity (9.81 m/s^2 or 98.1 N/kg)
- h = head (m)
- h_p = pressure head, the difference in water levels (m)
- h_v = velocity head (m)
- v = velocity (m/s)
- Q = volume flow rate (m^3/s)
- t = time (s)

Mechanical and Electrical Operation

In order to design the wheel, it is helpful to know the mechanical and electrical design and how it works. To measure the flow rate using the bucket method:

1. Measure the bulk of the bucket or vessel. Save in mind that a classic 5-gallon container is regularly less than 5 gallons.
2. Discover a location along the place that has a waterfall. If none can be found, a waterfall can be created using a weir.
3. With a stopwatch, time how extensive it takes the waterfall to fill the vessel with water. Start the stopwatch concurrently with the start of the bucket being occupied and stop the stopwatch when the bucket seals. The bucket should not be filled by holding it below the surface of the watercourse because it is not the correct flow rate.
4. Record the period it takes to fill the bucket.
5. Reiterate steps two and three about six or seven whiles and take the average. It is an upright idea to do a few trial runs before recording any data so that one can get a sensation for the technique and dimensions required.
6. Only reject data if major problems ascend such as debris from the stream meddling with the flow.
7. The flow rate is the volume of the bucket divided by the average time it took to fill the bucket.To compute for the head, the following formula will be used:

$$h = h_p + h_v$$

where the velocity head is,

$$\frac{v^2}{2g}$$

Ideally, the wheel diameter should should be 90% of the head (Behrens, 2015),

$$D = 0.9\, h$$

The optimal rotational speed of the turbine wheel will be calculated by this formula for overshot water wheel:

$$Optimal\ rotational\ speed = \frac{21}{\sqrt{D}}$$

The power generated from falling water will be measured by the formula:

$$P = \eta \rho g h Q$$

Well designed overshot water wheels can reach efficiencies of 71% to 85% (Muller, 2004). In most literatures, the efficiency of an overshot wheel ranges from 60% to 80%. In order to get the expected power output, this formula will be used:

$$\%\eta = \frac{P_{out}}{P_{in}} \times 100$$

The number of the buckets is dependent on the wheel's circumference. The number of buckets is relatively easy to determine. The buckets should be approximately one foot apart, more or less. The buckets should be around one foot deep. Whereas the design rules permit for any width of wheel, for operational strength it is sensible to keep the ratio of diameter to width as near as feasible to 8 : 5. This is not a hard and fast rule, yet, and D:W ratios of up to 1:2 are utilized (Shannon, 2009).

As for this study is an applied research, the generator's specifications will be taken into consideration when it comes in the the designing stage. The rated speed and the rated voltage will be taken into account.

To choose the right rating of the inverter, the researchers will compute the total power requirement of the loads. Upon getting the total wattage required, the next step is to find the required VA rating of the inverter. The total Watt value (sum of wattage of all the loads) should be the same as VA value. But due to a factor called "Power Factor", it is not the same. For a residential house, the power factor is about 0.7 to 0.8 (to be super safe use 0.7 and to be economical use 0.8). So,

$$VA\ rating\ of\ inverter = \frac{Power\ Requirement}{Power\ Factor}$$

Battery is the support of an inverter structure. The presentation and lifespan of an inverter largely rest on the battery quality. Next is how many hours it can run all of the loads. This is called the battery capacity. It is the battery aptitude that chooses the running hours of the system. It is expressed in Ah (Ampere Hours). To compute for the battery capacity, this formula will be used:

$$Battery\ capacity = \frac{(Power\ Requirement)(Running\ Hours)}{Battery\ Voltage}$$

In this study, the researchers will use a 12 V Lead Acid battery. One major lead acid battery advantage is that these batteries do not require high maintenance to ensure its performance. With regards to the running hours of the system, farmers usually need the lightings at night so the researchers alloted a 12 hour running time.

The elecrical plan of the project will be made to show the electrical layout of the system and its load computation. These will serve as guide in providing the locale with the needed lightings.

To evaluate the system's effectiveness, the contributor's totals for each question on the SUS survey will be altered to a new number, added together and then multiplied by 2.5 to change the original scores of 0-40 to 0-100. Though the marks are 0-100, these are not percentages and should be measured only in footings of their percentile ranking. Based on research, a SUS score of 0 to 12.5 will be rated as "ineffective", 12.6 to 35.7 as "inconsistent", 35.8 to 71.4 will be rated as "slightly effective", 71.5 to 85.5 as "effective", and 85.6 to 100 will be rated as "very effective".

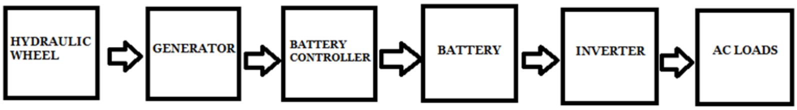

Figure 3. Block Diagram of the System

Figure 3 is the block diagram of the system. It shows the operation of the system from the input to the output. The turbine wheel converts the energy of water into mechanical energy. The generator converts the mechanical energy into electrical energy. The function of a battery controller in a hydro system is equivalent to turning on a load to absorb excess energy. Battery-based micro hydro systems require charge controllers to prevent overcharging the batteries. A battery provides a way to store energy when more is being produced than consumed. When demand increases beyond what is generated, the batteries can be called on to release energy to keep the loads operating. An inverter is connected to the battery to change the DC to AC that will be used to supply the loads.

Phase 3: Analysis Phase

In the analysis phase, the researchers will be conducting the following feasibilities to analyze data.

Technical Feasibility

In technical practicability, the following concerns are taken into consideration.

- Whether the necessary technology is accessible or not
- Whether the vital means are obtainable
  - Manpower- testers & designers
  - Hardware

The researchers administer a search/survey regarding the applicability of the materials to be used in the development of the turbine wheel generator. Retain in mind that a water wheel that essentially functions as it should last only a few years, and frequent conservation and maintenances are required to preserve it in top shape. The group lists the following materials:

- Wood
- Steel
- Plastic

Economic Feasibility

A Cost Benefit Analysis (CBA) will examine the economic feasibility. The paybacks of the project are summed, and then the costs related with taking that stroke are subtracted. The first step in the process is to collect a complete list of all the costs and benefits concomitant with the project. Costs should comprise direct and indirect costs, insubstantial costs, opportunity costs and the cost of potential risks. Then allocate monetary value to the benefits and cost. The final step is to quantitatively associate the results of the cumulative costs and benefits to determine if the benefits outweigh the costs. If so, then the sensible decision is to go forward with project. In not, a review of the project is defensible to see if adjustments can be made to either upsurge benefits and/or lessen costs to make the project viable. If not, the project may be abandoned.

In hypothesis testing, the test of the efficiency of the generator will be based on the power delivered in a certain period. The efficiency of the hydraulic wheel generator in this study will be computed by using the average power input and output.

Legal Feasibility

The legal feasibility includes study concerning contracts, liability, violations, and legal other traps frequently unknown to the technical staff. The project team has to make a thorough analysis of the legal issues surrounding the project, across several dimensions. A detailed legal due diligence should be done to ensure that all foreseeable legal requirements, which have not or will not be dealt with in other appraisal exercises, are met for the development of the project. Prior to the designing phase, the researchers will do a municipal interview regarding the bylaws covered by hydroelectric energy. The legal feasibility will contain the list of all the rules governing the topic to ensure that the project is legally doable.

Phase 4: Testing Phase

In the testing phase, the researchers will test the sustainability of the system by recording the charge and discharge time of the battery. The specified load will be connected to the battery and left operational until the battery reached the voltage cut – off of the load. The voltage cut – off is the voltage reading of the battery before the load stopped operating. The voltmeter was connected in parallel with the terminals of the battery. The voltage of the terminal of the battery determined the status of the battery. The discharging battery was monitored from full charged to completely discharge and vice versa. As the battery discharged, the terminal voltage of the battery was expected to decrease.

Operational Feasibility

An operational feasibility measures the acceptability of a solution. The researchers will list all the problems encountered when testing the device and the solution applied to solve the problem. The team will identify whether the power output of the system is enough to solve the problem of the farmers by showing the actual charging voltage of the battery.

Phase 5: Application Phase

The hydro generator will be applied on the water pump system. The system diagram is reflected on Figure 4.

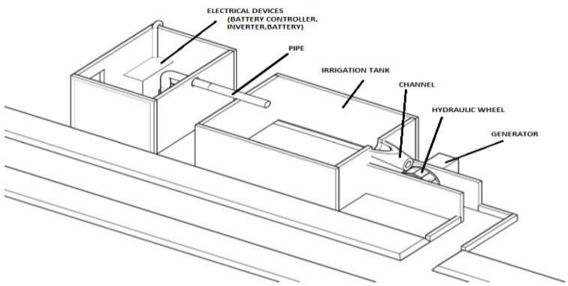

Figure 4. System Diagram

The researchers will also conduct a System Usability Scale (SUS) survey to evaluate the effectiveness (the ability of users to complete tasks using the system, and the quality of the output of those tasks) and satisfaction (users' subjective reactions to using the system). The SUS includes 10 questions, which will be asked to the respondents to complete. Farmers will answer each question by ranking from 1 to 5. 1 means they strongly disagree, 5 means they strongly agree, and 2 and 3 are somewhere in the middle.

RESULTS AND DISCUSSION

To evaluate the project's technical practicability, the proponents listed three possible materials, which the water wheel can be made of. The advantage and properties of each material were carefully assessed to come up with the best.

Water wheels are usually constructed from wood. Traditionally, water wheels were made of cypress or white oak. Both of these materials are expensive to source, but they are highly rot-resistant. Pine is inexpensive, but it may only last a couple of years when exposed to the elements. Though another popular choice, red oak is a porous wood and therefore not the best option for a working water wheel and it offers little in the way of durability over time.

Plastics have numerous properties that make them superior to other materials in many applications. Plastics generally have: resistance to corrosion and chemicals, low electrical and thermal conductivity, high strength-to-weight ratio, colors available in a wide variety and transparent, resistance to shock, good durability, low cost, are easy to manufacture, resistant to water and have low toxicity. In fact, plastic refers to a state of the material, but the material itself: synthetic polymers commonly called plastics are actually synthetic materials that can achieve the plastic state, i.e. when the material is viscous or fluid, and no resistance properties to mechanical stress.

Stainless steel is not a single material but the name for a family of corrosion resistant steels. Stainless steel is more expensive than standard grades of steel but it has greater resistance to corrosion, needs low maintenance and has no need for painting or other protective coatings. These factors mean stainless steel can be more economically viable once service life and life cycle costs are considered.

Galvanized steel is steel that has gone through a chemical process to keep it from corroding. The steel is coated in layers of zinc oxide because this protective metal does not get rusty as easily. The coating also gives the steel a more durable, hard to scratch finish that many people find attractive. For countless outdoor, marine, or industrial applications, galvanized steel is an essential fabrication component. Upon assessment, the proponents decided to use galvanized steel in making the water wheel. Galvanized steels are easily accessible and obtainable. The group considers the galvanized steel for it is not only inexpensive but it has also the properties that can make it last for years.

The economic feasibility of the study is assessed by a Cost Benefit Analysis method. The total cost is compared to the possible benefit of the project to prove its viability. The total expense of the whole project is ₧20,500.00 which includes the materials, and electrical layout of the system. When connected to a cooperative, the annual electric bill of the farm is ₧7, 268.69 with a rate of ₧10.0954 per kWh. In three years' time, the total electric bill will be ₧21, 806.064 which means after three years of investment in a hydroelectric system, the user of the project will benefit.

A legal feasibility is accomplished to secure that the hydroelectric project is legally doable. The proponents interviewed the municipal lawyer of Guagua, Pampanga and luckily answered certain questions regarding the bylaws governing hydroelectricity system installation.

The law under Republic Act No. 7196 otherwise known as "Mini-Hydroelectric Power Incentive Act" governs hydroelectricity. The law aims to encourage entrepreneurs to develop potential sites for hydroelectric power existing in the country by granting the necessary incentives, which will provide a reasonable rate of return. The law has for its objective the attainment of energy self-sufficiency and thereby minimizes dependence on outside source of energy supply.

When the developer fails to faithfully comply or perform any and all of the obligation under and pursuant to the contract, the performance bond or other guarantee of sufficient amount in favor of the government and with surety or sureties satisfactory to the Office of the Energy Affairs will be forfeited in favor of the government.

To make a hydroelectric system legally doable, the applicant must prove that the operation of the proposed mini-hydroelectric project and the authorization to do business will promote the public interest in a proper and suitable manner and to formulate, in consultation with the National Economic and Development Authority (NEDA), and the Department of Trade and Industry (DTI) standards to measure the technical and financial capacity of the developer.

For the assessment of the prototype, the operation of the water wheel and the generator were monitored during the charging time of the battery to compare the mechanical efficiency and the electrical efficiency of the system. The data gathered from the observation of the charging time were drafted to a line graph for evaluation. The efficiency on both aspects showed if the difference on the two is significant. The parameters being assessed are: Output Voltage and Current Readings, Mechanical Power Input and Output, Electrical Power Input and Output, and the Charging and Discharging Time of the Battery

Another parameter to be considered in assessing the prototype is the sustainability of the system by comparing the time of charge and discharge of the battery. The evaluation of the prototype is based on the data gathered and interpreted. It is to know whether the battery can support the loads up to 12hrs of operation.

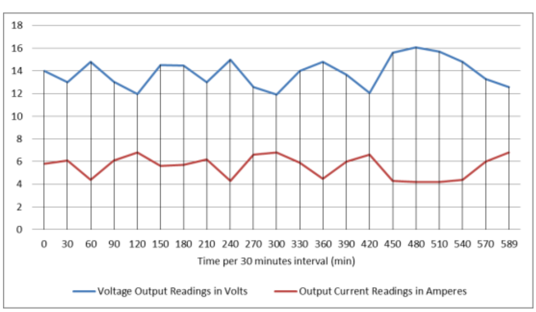

Figure 5. Output Voltage and Current Reading of the Generator

The generator drawn 14 V with a current of 5.8 A on its initial operation and 12.59 V with a current of 6.8 A on its final operation before the battery is fully charge. Figure 5 shows the output voltage and output current of the generator respectively. The voltage and current varies immensely as time passes by. It is because these parameters depend on the mechanical speed provided by the water wheel. As speed increases, voltage provided by the generator also increases. These graphs illustrate that as the voltage increases, the current decreases.

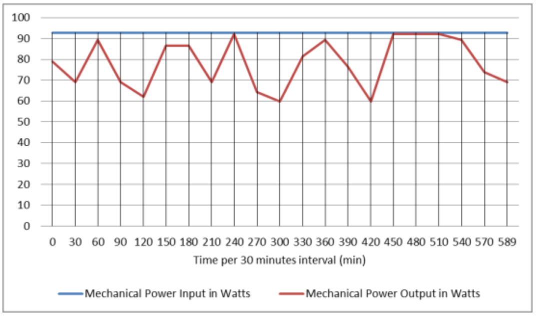

Figure 6. Mechanical Power Input and Output

Figure 6 shows the water wheel's power output and power input during the charging period. The initial mechanical power output is 78.83 W just as the water hits the water wheel. The output power drawn from the generator just as before the battery reaches its full charge state is 68.99 W. These powers are calculated based on the input volume flow rate of water and the angular velocity of the wheel. This graph illustrates that there are some losses when water energy is converted by the water wheel into useful rotational mechanical energy.

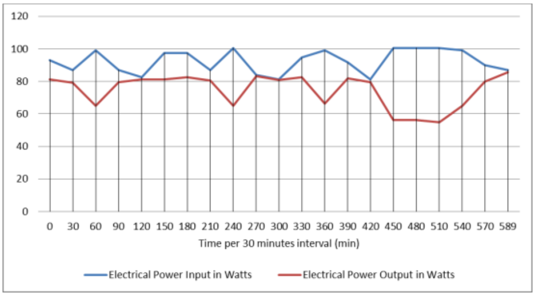

Figure 7. Electrical Power Input and Output

Figure 7 shows the generator's power input and power output rating during the time of charging. The generator's power changes dramatically for its output and input parameters depend on the speed provided by the water wheel. On the first time of charging, the generator gives out 81.2 W as a result for an input power of 93.06 W. Moreover, on the time before the battery charges full, the generated input and output power is 87.06 W and 85.61 W respectively.

The battery consumes 10.32 hours to fully charge a battery and 31.2 hours to completely discharge it. This only shows that the battery can sustain the 12-hour operation of the loads in the farm. The proponents solved the main problem of the farmers, which is lighting issue by constructing a hydraulic water wheel generator that can provide power to charge a battery. Figure 8 shows the actual charging voltage of the battery. These voltage readings are measured from the discharge state to fully charge state.

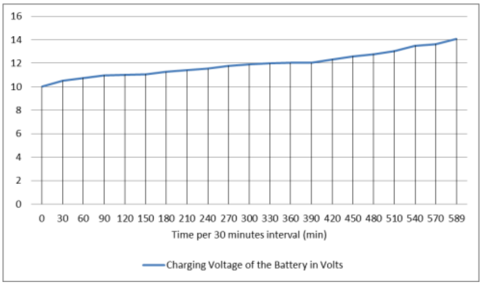

Figure 8. Voltage Reading of the Battery during Charging Period

The test of the efficiency of the system is based on the power the generator delivered in a certain period of time. Table 1 shows the mechanical efficiency, electrical efficiency and the overall efficiency of the system. The efficiency of the system in this study is computed by using the average power input and output.

Table 1: Efficiency

	Mechanical (W)	Electrical (W)	System Overall (W)
Average Power Input	93.92	92.42	93.92
Average Power Output	78.18	76.23	76.23
Efficiency	83.24	82.49	81.17

Typically, the critical value used by other researchers was 5% since not all study was sophisticated. The computed coefficient *r* is greater than the tabular value with a critical value 5%. If the Pearson *r* is less than the tabular value, the null hypothesis should be accepted, thus there is really no significant correlation between the parameters compared. If the Pearson *r* is greater than the tabular data, the null hypothesis should be rejected and the alternative hypothesis should be accepted, thus there is really a significant correlation on the parameters being compared. And since the computed value of the coefficient *r,* which is -0.89 is greater than the tabular data of a 5% critical value, thus the null hypothesis is rejected and the alternative hypothesis is accepted. There is a significant correlation between the mechanical efficiency and electrical efficiency of the system. The verbal interpretation of *r* shows that there is a very high negative correlation between the two efficiencies. It indicates a negative association, that is, as the value of one variable increases, the value of the other variable decreases. It demonstrates the negative relationship between the mechanical efficiency and the electrical efficiency of the system. As mechanical efficiency increases, electrical efficiency decreases and vice versa.

The SUS Survey is conducted to evaluate the system's effectiveness based on the farmer's assessment upon using the system. Figure 9 shows each farmer's response score in using it. The system got an average score of 94, which falls under the range of 85.6 to 100 that is to be labeled as very effective. As of for the farmer's decision, the system is effective and convenient to use.

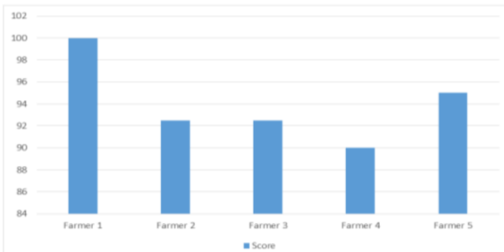

Figure 9. SUS Survey Scores

CONCLUSION

The main objectives of the study, which are to make an energy-harvesting device from water movements as a source of electricity and to generate electrical power that will supply loads such as lighting loads and batteries for flashlights, were achieved by designing a hydraulic wheel generator that can regulate the water pressure and flow during the water pump operation. By harnessing the energy of water converting it to electrical energy, the generator supplied enough power to charge a battery that can be used for illumination and charging purposes.

It is proven through test that there is a significant correlation between the mechanical efficiency and electrical efficiency of the system. As the value of one variable increases, the value of the other variable decreases which means that when mechanical efficiency increases, electrical efficiency decreases. One property, which may affect the two efficiencies, is the water wheel's gearing and construction. These affect the output speed of the prime mover and the input speed in the generator. Furthermore, the volume flow rate of the water also shares a great portion in each efficiency especially when it comes to the prime mover's rated speed for it acts as the driving force.

Through a survey, the system is graded as very effective for it solves the respondent's problem about lighting issue. The system can charge a 12V 100Ah battery for almost 11hrs that can sustain an at least 2 days of charging and illumination, thus it proves that the system is well designed to generate power from falling water.

The gearings of the water wheel may be adjusted to maximize all the force supplied by water to produce great number of revolutions, which can increase the voltage output of the generator. Additional loads are also applicable but the discharging time of the battery may shorten depending on the amount of loads connected to it. A boost converter may be used to lower the discharging time of the battery. The system may also be used with some other kinds of battery such as lithium ion to see its response. Further study about water wheel types is also recommended to determine which better suits a certain locale.

REFERENCES

1. Drew, B., Plummer, A. R., & Sahinkaya, M. N. (2009). A review of wave energy converter technology: Sage Publications Sage UK: London, England.

2. Khaligh, A., & Onar, O. C. (2010). Energy harvesting. *Solar, Wind, and Ocean Energy Conversion Systems, Boca Raton, FL: CRC Press, ISBN, 978*, 1-4398.
3. Zhu, G., Su, Y., Bai, P., Chen, J., Jing, Q., Yang, W., & Wang, Z. L. (2014). Harvesting water wave energy by asymmetric screening of electrostatic charges on a nanostructured hydrophobic thin-film surface. *ACS nano, 8*(6), 6031-6037.
4. World Energy Council (2016). Retrieved from https://www.worldenergy.org/data/resources/resource/hydropower/
5. Southeast Asia's First Ocean Tidal Power Plant To Be Built In Philippines. Retrieved from https://philnews.ph/2017/01/26/southeast-asias-first-ocean-tidal-power-plant-built-philippines/
6. "History of Hydropower | Department of Energy". energy.gov. Retrieved 2017-05-04.
7. Hydrokinetic Power (2016). Retrieved from http://www.hydroquebec.com/sustainable-development/documentation-center/hydrokinetic-power.html
8. Thomson, Ross (2009). Structures of Change in the Mechanical Age: Technological Invention in the United States 1790-1865. Baltimore, MD: The Johns Hopkins University Press. p. 34. ISBN 978-0-8018-9141-0.
9. Power in the landscape. "Types of water wheels". Retrieved 12 February 2017.
10. Stream wheel term and specifics (2017). Retrieved from https://en.wikipedia.org/wiki/Water_wheel#cite_note-PITLtypes-9
11. Behrens, Rudy (2015). Design calculations for overshot water wheels. Retrieved from http://www.backwoodshome.com/design-calculations-for-overshot-waterwheels/

12. Muller, G. (2014). Water wheels as a power source. Retrieved from g.muller@qub.ac.uk
13. Shannon, R. (2009). Water wheel engineering. Retrieved from http://permaculturewest.org.au/ipc6/ch08/shannon/index.html