Senior Design Project Proposal: Underwater Dam-Free Hydrokinetic Turbine

The Turbinators:

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EBS 170A

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I have reviewed this project proposal with the student engineers and I find it to be technically sound and feasible.

Name ______________________ Signature _________________________ Date _______

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Executive Summary

In Kafue, Zambia, fishing on the Kafue River is a way of life. In order to keep the fish product cold on the way to market, ice currently has to be imported. This is an expensive endeavor. The clients, Robert Shimaingo and Steven Nvula, have designed and implemented a dam-free turbine system in Kafue. Their goal is to use the river to power a generator that in turn powers a refrigerator used for fish storage. This will be an environmentally friendly solution that reduces dependence on ice and allows fisherman to save money. The turbine system will be replicable for other fisherman on the Kafue River. The Turbinators' project focuses on maximizing the efficiency of the current dam-free turbine system in order to guarantee full power generating capacity for the local fishermen.

Over the next two quarters, the ultimate goal is to create a complete model of the system as well as build a testable prototype of the gearbox setup. It will be designed and constructed using parameters from Shimaingo, and the prototype will be tested in Davis, California. Our specific objectives are to achieve the rated output of the generator by designing the optimum gear ratio, and to minimize losses, which will decrease the noise and excess heat generated by the system.

At the end of this project we will have tested and redesigned our prototype, created a general system model including recommendations for improvements, and modeled the prototype in SolidWorks. The majority of our $500 budget will be spent building the prototype. We will be working with partners at MIT and additional professors at the University of California, Davis to design a testing plan and acquire necessary materials. The Turbinators' are dedicated to the success of this project and the opportunity to share our engineering experience with those who can benefit from it.

Problem Statement and Background Material

Background Information

In Kafue, Zambia, fishing supports many of the local inhabitants. Once the fish are caught, they must be transported from the Kafue River up to market. The fishermen must keep the fish cold from the time they are out of the water to the time they are sold in order to avoid spoilage. If the fish cannot be kept chilled, the fishermen are forced to reduce their prices and make less profit at the market. The current solution of using ice blocks as a way to maintain a cold temperature is not economically sound and is more energy intensive. This project aims to provide an efficient and environmentally conscious solution for keeping the local fishermen's fish cold. We are working remotely with Robert Shimaingo and Steven Nvula and their team in Zambia.

Technical Overview

Synchronous generators operate when the waveform of the generated voltage is synchronized with the rotation of the generator so that the magnetic field of the rotor is supplied by a permanent magnet, which requires no rotor field excitation. The output frequency (supplied to the refrigerator) is locked to the shaft frequency (from the gearbox) so that they are running at the same speed (Howey). The frequency is determined by the formula $f = (RPM * pole\ number) / 120$. This type of generator is ideal for our system because it can run alone without a connection to a larger grid. They can also accommodate load power factor variations, which is ideal for this project, as the flow of the river is bound to change with the flood cycle and dam activity (Electway Electric).

Gearboxes convert low-speed turbine shaft rotation to high-speed rotary motion necessary for a generator to produce power (Wind Turbines). Gearboxes increase output torque, which changes the speed of rotation (Gearboxes). Most gearboxes are constructed from steel materials such as iron, aluminum and brass (Gearboxes). If the initial gear is rotating clockwise then the gear it engages will be rotating counterclockwise. This pattern continues down the line of gears. One important design feature of a gearbox is the gear ratio, which is defined as a correlation between the numbers of teeth on the two engaging gears (Gearbox). The output torque is dependent on the gear ratio used and the torque is inversely proportional to the speed (Gearboxes). The number of teeth is proportional to its circumference of the gear.

In gearbox applications for low-speed systems, straight gear teeth are generally used as opposed to helical (as in high-speed gearboxes) (Gearboxes). Low-speed gearboxes are generally noisy and have lower overall efficiencies than high-speed applications (Gearboxes). There are many types of gearboxes. Figure 1 shows two different gearbox arrangements, the fixed-axis and planetary. Some types of gears include bevel gears, helical gears, spur gears, worm gears and planetary gears (Gearboxes). Spur gears are a cost effective choice for high gear ratios and high torque (Gearboxes). The term "backlash" refers to the angle in which the output shaft of a gearbox can rotate without the input shaft moving (Gearboxes).

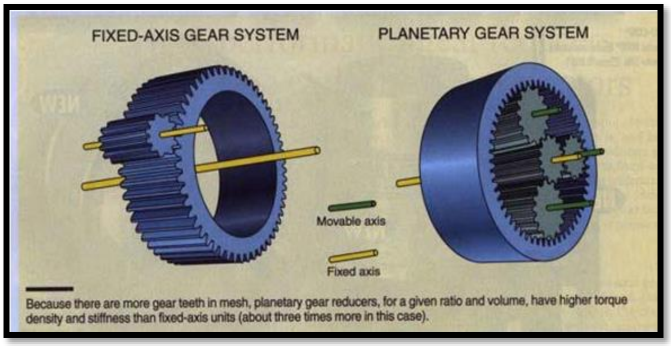

Figure 1: *Illustration of different gear system options*
Source: http://www.anaheimautomation.com/manuals/forms/gearbox-guide.php#sthash.LUKlYSMt.dpbs

When two gears are in mesh, the product of the speed and the number of teeth is conserved. This allows for the relationship $Speed_1 * Teeth_1 = Speed_2 * Teeth_2$ to be used in order to calculate either the necessary speed or number of teeth (Gear Ratio Calculations). Based on gearbox characteristics, the power of each gear can be calculated. From the power ratio, the gearbox efficiency can be calculated (Pont). Many of the dimensions used in parameter calculations are labeled in Figure 2.

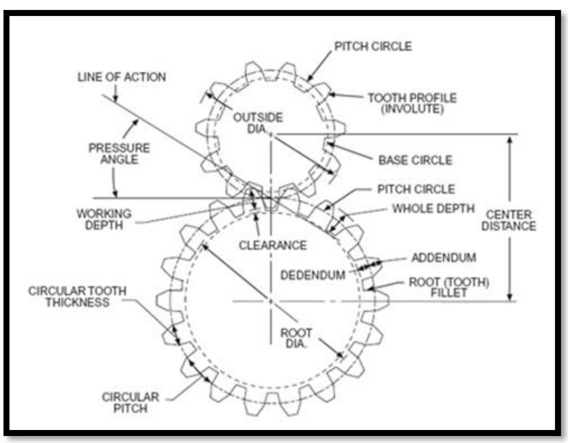

Figure 2: *Gear Parameters*
Source: http://www.anaheimautomation.com/manuals/forms/gearbox-guide.php#sthash.LUKlYSMt.dpbs

Problem Definition

The turbine system that the client in Zambia has designed is currently active and functioning. The problem, then, is that it is not operating at peak efficiency or optimum output. One of the main difficulties that the client is encountering is that the gearbox in the system is causing power loss due to inefficiencies. The gearbox's gears do not mesh correctly, and therefore they are misaligned and do not achieve a pitch line. A pitch line is the ideal line at which corresponding gears will fit together to have a common velocity. In addition, the generator may need to be adapted in order to increase the output from this element. Not only is it connected to a less than ideal gearbox, it is connected to the voltmeter and not the wattmeter so we cannot accurately determine the electric power of the system.

Robert is passionate that this system is made accessible for fisherman in Zambia to build. This means while prototyping it will be important to use materials available in Kafue. Part of our final project will involve recreating or at least testing parts of the improved system, which means that we foresee problems in the travel and location of pieces to build a prototype.

Needs and Importance

With a universal focus on reducing emissions in order to mitigate climate change and maintaining global biodiversity that is rapidly declining, the problem of providing a green and sustainable solution to local power generation is needed more so today than ever. A dam-free turbine system is significant in the modern world in the following ways.

First, the "dam-free" constraint is extremely important to the Kafue Flats region in Zambia. The town of Kafue lies between two hydroelectric power-generating dams, 270 km apart, that border the Kafue Flats – the Itezhi-tezhi dam (west of the town of Kafue) and the Kafue Gorge dam (east of Kafue) (Mumba). The Itezhi-tezhi dam was built five years after the Kafue Gorge dam in order to provide the necessary flow for power generation at the Gorge dam (Mumba). This pair of dams has had very negative impacts on the hydrology and ecology of the Kafue flats, including altering the natural flood patterns of the area and allowing for invasive species to move in and threaten native flora and fauna (Mumba). Therefore, the significance of implementing power-generating systems along the Kafue River without the use of dams cannot be understated.

Second, powering a load, such as a refrigerator, by using free-flow water power eliminates the need for using fossil fuels to chill fish. This has a neutral effect on the global climate, and does not emit greenhouse gases that cause global climate change.

Third, the solution to this problem eliminates the need for using ice to chill the fish. Currently, ice used to keep the product cold comes from towns outside of Kafue, such as Mazabuka and Lusaka, which are about 51 and 27 miles away, respectively (Shimaingo). The ice itself and the transportation are expensive, and most likely involve transportation that uses fossil fuels (Mwambazi, Shimaingo). In addition, due to the high temperatures in Zambia, the ice melts quickly and therefore cannot complete its purpose (Mwambazi). Clearly, an alternative solution is needed.

On a smaller scale, the importance of improving the efficiency of the gearbox and connected system is that the power generation needs of the client will be met. A smoothly running and reliable system will help the client towards his purpose. The system that the client has dedicated a lot of time to designing and building will work as it was designed for, and will improve the lives of the local fishermen and customers at the fish market.

Existing and Alternative Solutions

In 1998, Alaska Power & Telephone came up with the idea to place a turbine in the Yukon River next to their town, Eagle, Alaska, after wanting to reduce the use of diesel engines to provide electricity to customers. The river flows at about 2.4 m/s and has a maximum depth of 5.94 m in the winter and 9.91 m in the summer (due to snowmelt). Realizing that not all of the town's power could come from the turbine, the system was designed to produce maximum power of 100 kW with a 5 knot (2.57 m/s, only slightly smaller than the 3 m/s of the Kafue) flow. This power would help to supplement the load that averages 100 kW in summer and 120 kW in winter (Grimm). This is much larger than our proposed load because it was designed to provide power for a community grid, not a single refrigeration system.

Alaska Power's turbine measures 2.4 m in diameter and is reinforced with a heavy-duty ice deflecting cage. It is also ballasted with flotation tanks that can either be filled with river water to sink the system or pumped with air to bring it to the surface for maintenance. The generator produces a 60 Hz-750 VDC output that would be connected to the shore through a buried cable (Grimm).

After the turbine was put into place, the Eagle Project was analyzed to determine the maintenance feasibility. While at times it was successful at delivering 25-30% of the town's power, it also delivered 100% of steady 60Hz power for loads ranging up to 10kW for a standalone system. The project ran into a few technical problems such as the gear box overheating and the power inverters being tripped, caused by too narrow of a frequency response. These issues were solved by adding an external deck-mounted oil circulation and cooling system, and by putting in an inverter with a higher range of frequencies, respectively. Even though the turbine was operating well and could successfully provide power to the town, the project was abandoned because the associated costs of operating the turbine were much higher than those of the diesel plant; it was not economically feasible (The Alaskan Way). Our project differs in that we only need to be able to produce about 3 kW in order to power a refrigerator, not an entire town, so it is not only economically feasible compared to the current use of ice in Kafue, but it is harnessing energy to make the system environmentally green. This data demonstrates that this kind of project is feasible and has the capability to succeed so we can attempt to alter their design to fit our load.

One Garman turbine project has been in place since 1998 along the Nile River. A company called Caddet Renewable Energy wanted to provide clean water for displaced persons living in Juba, South Sudan, with the option to also generate electricity. The turbine in place has a diameter of 3.4 m and uses a two-stage belt transmission to link the rotor to a centrifugal pump, which carries water from the middle of the river to a water collection tank along the bank. The rotor has an efficiency of 30%, which means that out of all the power theoretically being generated by the turbine, 30% of this can be harnessed by the generator. This can be attributed to the use of locally fabricated blades with a constant hydrofoil section and a constant pitch. A voltage of 240 V can be generated by using a three-phase induction motor as a generator with an electric controller and a ballast load, which limits the current running through the system. This system also involved the use of a battery, which was charged using a permanent magnet alternator, which is used to increase the output power of the generator (CADDET Centre). This project allows us to see how a turbine can work without a gear box, which could be a possibility for our project. It also demonstrates alternate uses of the turbine (clean water pumping vs. power generation) that could be applicable for installation in other locations.

Solution Benefits

Re-designing the gearbox to achieve and appropriate gear ratio (possibly 1:162 as indicated by the client) will optimize the conversion from fluid power to mechanical power and finally to electrical power. The gearbox needs to be compatible with the functioning turbine system previously designed by Robert Shimaingo and Stephen Nvula. To ensure compatibility, the gearbox will need to be able to take as an input the output speed from the turbine, and put out to the generator the appropriate speed. This solution will decrease the power losses to the overall system and increase the total output power available supplied to a load, such as a refrigeration system or a battery for energy storage. Shimaingo has stressed that the entire system should be designed so that it can be replicated and used by other groups in Zambia to generate power from the Kafue River (Shimaingo). The gearbox will be designed using similar materials to those that are available in Zambia. A detailed model and building instructions will be included to make replication as straightforward as possible. The gearbox will achieve an output power of 3 kW from the generator (Shimaingo), and the system will most likely be generating power every day for many hours at a time. This system could potentially power a large refrigerator, which could be used to keep fish cold. If a battery element is added to the system to store energy during off hours, it would allow for remote use of a load (away from the power generator turbine in the Kafue River).

Goal, Objectives, Criteria, and Specifications

Ultimate Goal

Objective/Problem

Improve the overall efficiency of the mechanical to electrical power conversion system in the existing dam-free turbine complex.

Deliverable Goal

The ultimate deliverable for this project is to include a complete model of the gearbox and/or generator in SolidWorks, build and test an optimized gearbox set-up (with load).

Specific Objectives (Design Considerations)

I. Design for the correct gear ratio in order to run the generator at operating point (speed and torque) for the rated power output of 3KW.
II. Build and test the gearbox and its connection equipment to determine its performance and energy efficiency and deliver a gear box design that can be used to run the generator smoothly, quietly and reliably.
III. Easy to repair.
IV. Locally reproducible.

Design Project Plan

General Approach to the Problem

Our problem will be approached using the following steps:

- Problem definition
- Research prior art
- System modeling and analysis
- Establish design Considerations & Metrics
- Brainstorm possible solutions
- Idea selection
- Prototyping & Lab Testing
- Design refinement
- Evaluation & Documentations
- Field testing

To estimate the efficiency as a whole, a system model needs to be created. The basic working system model can be seen in Figure 3. The system is broken down into its components, including the river, turbine, joint, shaft, gearbox, generator, cables, energy storage and refrigeration. These parts can be seen graphically in Figure 4. For each component, the known parameters are included and the efficiency has been calculated or estimated. This model will be updated throughout the project as more information becomes available. The total system efficiency will also be updated. This information will allow proper selection of a load (refrigeration unit). It will also allow for recommendations on alternative cables, turbine blades or energy storage components to incorporate in the future.

RIVER		TURBINE		JOINT		SHAFT	
Velocity (m/s)	1.5 - 2.5	Turbine diameter (m)	2.8	RPM	64.9 - 107.1	RPM	64.9 - 107.1
Variability	?	RPM (60*Velocity/Radius)	64.9 - 107.1	Joint angle (deg)	30	Efficiency	99
Temperature	?	Torque (r x F) (m*)	?	Efficiency (%) Depends on joint angle	99		
		Efficiency (%)	30				
GEAR BOX		GENERATOR		CABLES		LOAD (ex. REFRIGERATOR)	
Gear Ratio	1 to 162	Input (RPM*Gear ratio??)	900-1600	Length (m)	500	Power Inpu	424
Torque	?	Max Power Output (kW)	3	Diameter (mm)	2.5	Running tin	24
RPM	?	Efficiency	65	Resistance (rho*L/Area) (O	1.71	Efficiency	70
Efficiency	50			Power Loss (I^2*R (Watts)	289		
				Efficiency (1-Power loss/3k	90.37		

Figure 3: *Basic system model with parameters*

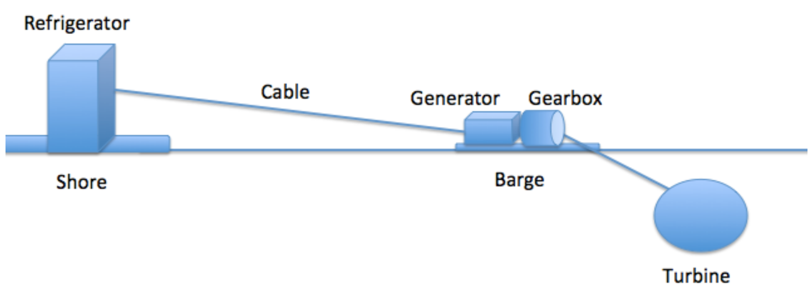

Figure 4*: Schematic of current underwater dam-free turbine system. Turbine power runs through shaft to gearbox and generator, through cable, and to load on shore.*

Commented [RHZ1]: What system? Add more words to be more specific: dam free turbine generator system

Proposed Solutions

Additional research will be conducted on the following:

- Improve existing gearbox design
- Belt and pulley system
- Off-the shelf solutions
- Redesign of generator to reduce rpm

Our initial solution is to improve the efficiency of the gearbox by increasing the gear ratio. However, we may propose the addition of something like a permanent magnet alternator to the generator, which if connected to the generator, could increase the efficiency and decrease the need for a high gear ratio. Instead of having it be 1:162, we could hypothetically use a ratio of 1:80, which would also increase the efficiency of the entire system.

Solution Selection Criteria

The technical specifications of the project are listed in a project report supplied by the client (See Appendix). Basic concepts of the components of the system are explained in the Technical Overview section. Currently the gear ratio is 1:30, meaning that the generator is rotating 30 times faster than the turbine and shaft combination. Our client would like a gear ratio of 1:162 in order to create more power in the generator. If we increase the efficiency of the generator, however, this may not be necessary.

The turbine needs to work with the couplings and the gear box. It also needs to produce enough energy to run the generator around an output of 3 kW, as this is the rated output of the generator that is currently in place.

Evaluation and Testing Plan

For the gearbox design, we know that the gear ratio need to be increased (possibly to 1:162). Through continued research, the possibility of manipulating the generator to lower the required gear ratio will be explored. By the end of this project, an optimized gearbox will be designed and fabricated. For applicable results, it will be tested with the same loading applied as if it were attached to the turbine and generator used in Shimaingo's design. A generator with a similar load can be used to simulate the current generator being used in Zambia. To simulate the turbine shaft and blades, a rotating shaft with applied resistance will most likely be used. Once the gearbox design has been finalized on paper, it will be modeled in SolidWorks to allow Shimaingo and his team as well as other individuals in Zambia to be able to replicate it. A dynamometer will be used to measure force and torque. From torque and angular speed the power and efficiency can be calculated. After designing, building and testing the gearbox we will use the collected data to update our system model.

Project Schedule

The Gantt chart in Figure 5 above shows how our team will proceed with the project. The major milestones are shown in bold in the first column. By the end of Week 5 of Winter Quarter, we must have the gearbox design completed in order to continue in a timely fashion. By the end of Weeks 8 and 9, we must have located all the materials we will need, bought the materials, built our gearbox prototype, and have tested and collected data on our prototype. This absolutely must be finished by the end of Winter Quarter in order to be able to finish the project by the end of Spring Quarter. In Spring Quarter, our milestones include redesigning our prototype based on our initial testing data, and preparing our project for the Engineering Senior Design Showcase. There is the possibility of some or all group members travelling to Zambia in Summer 2015 in order to work directly with the client and implement our design.

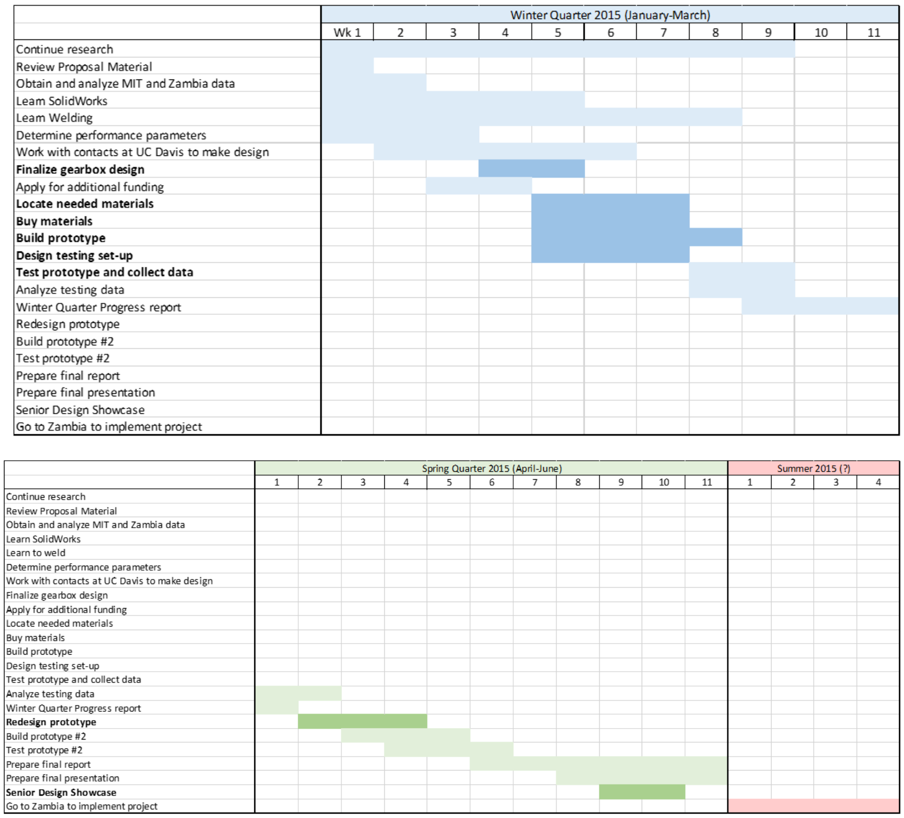

Figure 5: *Gantt Chart with project milestones*

Budget

UC Davis Program for International Energy Technologies (PIET) is providing $500 of funding towards this project. Funding will be needed for building the gearbox prototype. This will include buying the necessary gears, assembly materials, and housing for the gear system. A dynamometer will be needed to take measurements. A generator with a similar load will be needed for gearbox testing. A mechanism for modeling the applied resistance load of the turbine shaft. We will attempt to borrow a dynamometer and load simulating elements from labs on the UC Davis campus. Funding will be needed to purchase a SolidWorks license. A small amount of the budget will be dedicated towards transportation (to purchase needed materials) and communication (with Shimaingo and team in Zambia).

Table 5: *Budget breakdown*

	Estimated Expenses
Gearbox Prototype Materials	Dependent on design
Dynamometer	Borrow
Generator with similar load	Borrow
Turbine shaft and blade simulation mechanism	Borrow
SolidWorks	$150
Transportation	$40
Communication	$10

Our team is going to apply for the Blum grant offered by UC Davis in February. If received, this grant would supply $2,000 for continuing the project over the summer and potentially traveling to Zambia to work with Shimaingo and his team on implementation.

Deliverables

Table 1: *Expected deliverables for EBS 170 B and C*

Timeframe	Deliverable
Midway through Winter Quarter	Progress Report
End of Winter Quarter	Quarterly Report
Beginning of Spring Quarter	Draft for Final Report
Midway through Spring Quarter	Progress Report
Week 9 of Spring Quarter	Project Poster and Presentation for Design Showcase
End of Spring Quarter	Final Report

Resources

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Appendix – Project Report from Shimaingo Team

[Copied directly from the report received on November 10, 2014.]

Abstract:
The present preliminary report discusses the water turbine, with special emphasis on the design of the turbine, the challenges faced so far, required modifications and cost of estimates of the materials required to build the power turbine. The demand for storage facilities for the fishing communities in the Kafue plains has always been high as fishing is the most predominant economic activity in the area. The use of ice blocks is the most common method of preserving and storing the fish before it is transported to the market for sale, and this has proved to be both inefficient and expensive because when the ice melts before reaching the market huge losses are incurred by the fishermen. Therefore, there is need to come up with power generating station that will provide the community with both efficient and inexpensive option of storage for their fish. In response to the problem indicated above, a Kafue resident - Mr Robert shimaingo has designed and developed a water turbine that will harness the potential energy of the water and convert it to rotational energy, which will be used to run a generator. The generator will be used to provide electricity to power the cold storage facilities.

BACKGROUND

In recent years, demand for renewable energy has increased significantly. The development of devices utilizing clean energy such as solar, wind, water, geothermal, and fuel cells attracts more and more attention. Water energy harvesting has for a very long time developed an important role as a global energy source. Hence, many researchers and innovators are looking for ways to harness the potential energy of water to produce electricity as construction of dams has proved to be a very costly and time consuming venture.

Therefore, the need to design and develop a mobile response turbine of propeller type that will harness the natural flow of the water of the Kafue river and its potential energy and through a set of speed-up gears to run a single phase synchronous AC generator rated at 3kW power, voltage of 230V, 13A current and rotation of 1500rpm at 50Hz frequency cannot be overemphasized.

INTRODUCTION

A water turbine is a rotary engine that takes energy from moving water. The source of water can either be from the river, dam, and falls.

The design of this particular water turbine started in the year 2010 by Robert shimaingo and his team along the banks of Kafue River. The idea and motivation behind this turbine is to help people living in rural areas along rivers where there is no electricity, who are is involved in catching of fish for sale at a larger scale to have storage facilities like fridges.

The turbine that has been designed falls under the category of the reaction turbine. A reaction turbine is a type of turbine that is found in areas of low head and high flow rate of water. The turbine in question has its design similar to a propeller- type reaction turbine and the Aquair UW water turbine. Pico hydro is a term used for hydroelectric power generation of under 5 kW. It is useful in small, remote communities that require only small amounts of electricity - for example, to power one or two fluorescent light bulbs and a TV or radio in 50 or so homes. Even smaller turbines of 200-300W may power a single home in a developing country with a drop of only 1

meter. Pico-hydro setups typically are run-of-stream, meaning that dams are not used, but rather pipes divert some of the flow, drop this down a gradient, and through the turbine before being exhausted back to the stream.
Like other hydroelectric and renewable source power generation, pollution and consumption of fossil fuels is reduced, though there is still typically an environmental cost to the manufacture of the turbine, generator and distribution methods.

Electric Generator 3KW Synchronous AC Generator

Figure 1: generator assembly attached to a step-up gear at workshop.

The ST/STC series generators are mainly designed to serve as power generating unit of small capacity which supply electricity for lighting purpose in ships as well as for household electric devices used in towns or villages. The construction of the generators is of drip proof, salient pole rotating field self-excitation and constant voltage type. The alternator inside is used with high quality electric magnetic and electrical materials. Stator insulation is of Class E (or B).rotor insulation is of Class B.
Specifications
Phase: 1
Place of Origin: China
Brand Name: FUAN LIYUAN
Output Type:AC Single phase
Speed: 1500RPM
Frequency: 50Hz
Rated Power: 3KW
Rated Voltage: 230V
RatedElectric Generator Current: 13A
Type:Electric Generator 3KW
Material: Cold roll stator & 100% copper
Pole number: 4
Structure: Asynchronous generator

Feature: Brush Generator
1. Altitude: not exceed 1000m.
2. Cooling air temperature: 258~313K (-15oC~40oC).
3. Relative air humidity: not exceed 90%.
The distance from the location of the turbine to the island is approximately 500meters, hence there is needed about 1km of a pair of electric cables to transmit the electricity and two polls, one

to be mounted on the turbine and the other on the island.

RATIONALE

The fishing community of the Kafue plains, which currently does not have any electricity supply rely on blocks of ice to preserve their fish stock as it is being store and transport to the market for sale. This is very risky and expensive as due to high temperatures and transport breakdown the ice tends to melt, and expensive in the sense that it is acquired from places such as Mazabuka town and Lusaka then transported to the area. Hence, being able to generate electricity in such an area will enhance the livelihood of the fishing community in an economic and social way.

PROBLEM STATEMENT

For generations, people living in rural areas involved in fish business have been having problems on how to preserve fresh fish due to lack of storage facilities such as fridge, thereby hindering them from expanding their fishing activities .Hence the need of a reaction turbine that will be able to produce power in low water head to power the communities around rivers where fishing activities take place. This can enable them to start buying deep freezers fridges for stocking fish at the large scale.

OBJECTIVES

To determine the current efficiency, capacity and performance of the turbine developed by the project promoter.

Design and develop a water turbine electricity generation station.

To conduct tests on the improved turbine, so as to determine the improved parameters.

ASSESSMENTS MADE ON THE TURBINE

The water turbine designed lacks the following

The blade angles on the turbines are not known and the blades do not have the uniform profile. The surface area of the blades is not wide enough.

Material used to construct the turbine is mild steel which is rusty. This will compromise on the life of the turbine.

The water flow velocity of the Kafue River on which the testing of the turbine was done is not known.

The generator is connected to the volt meter instead of the wattmeter. The gear meshing - gears being used are not supported by engineering standard

because the gear teeth have different face widths, the pitch line is not achieved The selections of gears have been done without considering the gear ratio and particular output. This is costly and time wasting. The drive gear has 129 teeth and the pinion gears tested has 29, 20 and 17 teeth.

The figure below shows the meshing

The picture shows the gears meshing. It clearly shows that the spur gear gears have not been designed for each other. The gears can be observed to be misaligned.

WORK DONE
Assessed the project
Consulted with UNZA- TDAU and MECHANICAL WORKSHOP

WORK TO BE DONE
Introducing technical knowledge into the designed turbine
Design of the turbine
Coming up with suitable gears and making the designs
Measuring the torque transmitted through the shaft
Measuring the speed of the flow of water on the Kafue river
Make simulations using SOLID WORKS
Implement the changes on the current designed turbine
Cost analysis and estimates
Make recommendations

REQUIREMENTS FOR WORK TO BE DONE
Flow metre Torque metre Digital multimetre

The picture below shows the actual turbine on the testing site on the Kafue River, raising his hand is Robert Shimaingo

The picture shows the current Zambian team working on the underwater turbine project. Robert, Stephen, Sydney, and Isaac (L to R).