Concept Generation and Selection Document

EML 4551C – Senior Design – Fall 2011 Deliverable

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Introduction

Power generation is one of the most important processes that take place on all around the world every day. In developed, first-world countries power generation serves as an additional “necessity” for a comfortable living. However, in a large amount of third world countries power generation is a scarce and sometimes non-existent luxury. In African countries, excluding South Africa and Egypt, it has been estimated that a maximum of 20% of the population has access to power. The main reason for these low numbers is that power generation is costly, specifically because of its requirement of expensive fuels, processing units, storage units, and distribution systems.

The concept of power generation has been a subject for continuous improvement. These improvements have come with an expansion in the variety of energy sources, as well as conversion systems and in the concentrations and types of exhaust emissions. Throughout the majority of the history of power generation, sources such as coal, petroleum, and natural gas have been the most predominant. They still continue to be the most common today. However, because of the amount of dangerous exhaust emissions and rise in greenhouse gas concentrations, a turn towards renewable energy has advanced research and technologies to create systems that are environmentally clean and low cost.

Renewable energy is defined as energy coming from a source that is always present and is naturally reproduced by the Earth. They are considered to be emission free sources or sources that are environmentally safe. Some of the main types of renewable energy sources include solar, wind, water, and geothermal.

Solar Energy

Solar energy is primarily collected with a series of photovoltaic cells, or CSP (Concentrated Solar Power) systems. Photovoltaic cells were initially composed a pure mono-crystalline material that was efficient, but very expensive. Advancements in synthetic materials were able to drop the cost, but also decreased the overall efficiency. The newest technology combines both technologies to achieve a higher efficiency with a lower cost. CSP systems concentrate radiation from the Sun in a small area, and use the thermal energy to drive a heat engine that produces power. Both of these solar systems are highly expensive relative to other renewable sources.

Figure A – Photovoltaic Solar Cell

Wind Energy

Wind energy is low cost energy source that requires a rotating turbine either in a vertical axis configuration or a horizontal axis configuration. Some of the drawbacks to this renewable energy source include its dependence of wind speeds and geographic locations. Most wind generating turbines are built at high elevations to reduce the effect of the ground boundary layer that is formed through friction between the solid ground and flowing wind.

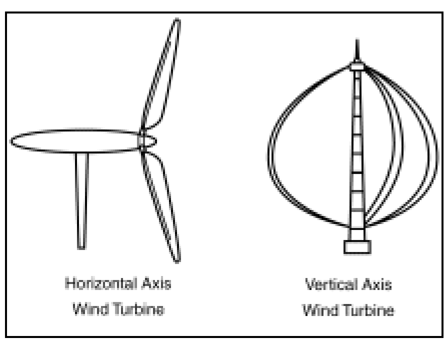

Figure B – Horizontal and Vertical Wind Turbine

Water Energy

Water power consists of collecting energy stored in flowing or falling water. When water energy is used to make electricity it is considered hydropower or hydroelectric power. Hydroelectric power plants are widely implemented and are composed of a large dam which channels the water, which is then used to spin a turbine. An advantage of water is that it has a very high density when compared to air, therefore, stores a much larger amount of energy.

Figure C – Water Wheel Turbine

Geothermal

Geothermal energy uses heat that is trapped within the Earth for capturing energy. This heat is located beneath the ground and varies in depth depending on geographic location. The heat beneath the Earth can come from warm water located at shallow levels beneath the ground, or from molten rock (magma) located several miles deep.

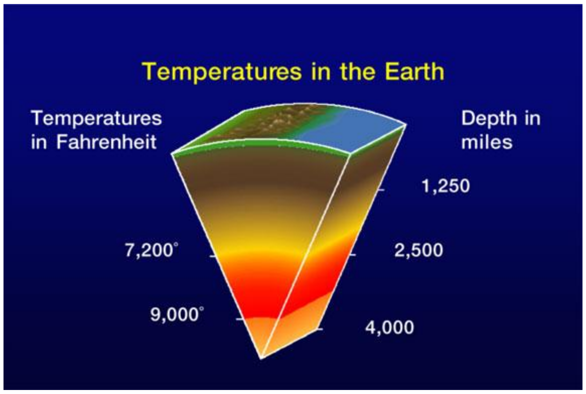

Figure D – Temperature Range in Earth Depth

Problem Statement

Design and construct a power generation system that implements the use of a renewable energy source, and is composed of entirely recycled materials.

Objectives

- Power generation unit must be capable of generating 100 W/day and must be able to store 300 W*h
- The output of the unit must be in 12V DC
- Final cost of the design must be under $50.00

Constraints

- The power generation system must be designed to meet the objectives in three different geographic locations in third world countries

Motivation

The main reason behind the project is to create an effective and affordable power generation system to people from third world countries. Specifically, people who have limited or no access to electricity and very low financial resources. This project will also promote renewable energy and demonstrate the amount of value that recycled materials contain. Many materials that are constantly trashed can be reused in significant ways and should be conserved.

Design Concepts

Design Concept #1 – Vertical Axis Wind Turbine (VAWT)

A wind turbine converts the kinetic energy of wind into rotational mechanical energy. A vertical axis wind turbine as seen in Figure 1 mounts the turbine in a vertical orientation, which is contrary to horizontal axis wind turbines (seen in next design concept #2). In this system, the turbine will spin with any wind hitting it in the horizontal direction, meaning the system is Omni-directional. The VAWT's rotational mechanical energy will be harnessed by an alternator. Both the VAWT and alternator will be connected with either a belt or gear system that will increase the rpm according to the alternator specifications. Most automobile alternators run anywhere between 700-7000 rpm. The turbine design will be dependent on what materials are found in the field, but will most likely be made out of a halved pipe or tube. This would allow for a simple blade design, but the most adequate will be decided upon physical tests.

One of the advantages of using the VAWT system is that since it is Omni-directional, it does not have to have an active or passive control system to keep it facing into the wind. VAWT's are also efficient at low wind speeds, which are a huge advantage as it allows implementation at close to ground level. In order to keep the cost of the VAWT affordable it is essential to keep its design as simple as possible. There must also be careful consideration into the materials used to construct the system and research on materials that are available in the three specific geographic locations. Another consideration is the average wind speed of the locations. Wind speeds are always greater at higher elevations, due to the boundary layer effect. Therefore, the system must be designed accordingly to be effective. A possible solution for higher wind speeds is to design a VAWT system that will be placed on top of a roof of a house or a building.

In addition, an external surface will need to be implemented due to the Omni-directional nature of the turbine. If the wind were to hit the turbine blades directly, only half of the energy available is hitting the turbine in a positive manner, the other half is absorbed by the counter-rotating turbine blade and puts an incredible amount of drag on the system. This greatly decreases the turbine's efficiency and also means that the turbine can never rotate as fast as the input wind speed. The external surface must be added to the system to block the wind hitting the turbine blades and guide the wind in the direction of rotation prior to reaching the turbine. A possible solution that can be performed is to cut slits in a 55 gallon drum and twisting them to a certain angle, and ensure. An example of this can be seen in Figure 2.

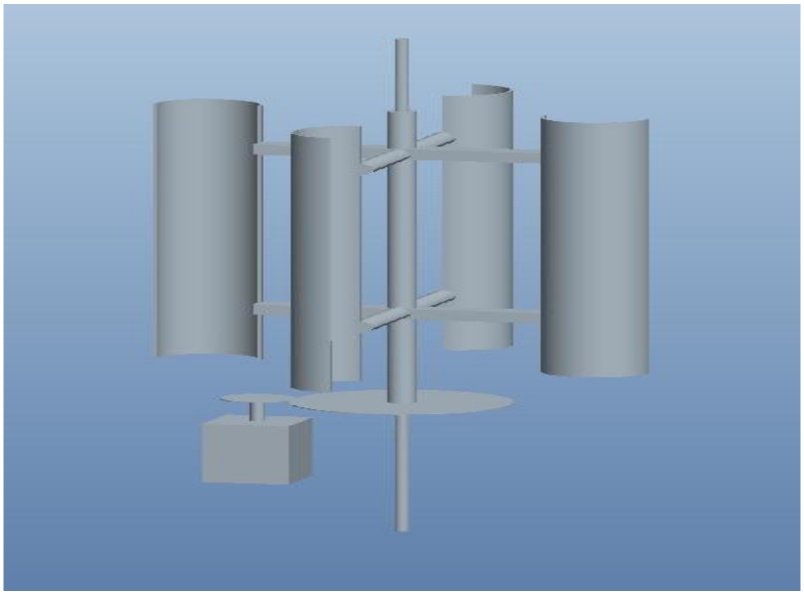

Figure 1 – Vertical Axis Wind Turbine (VAWT)

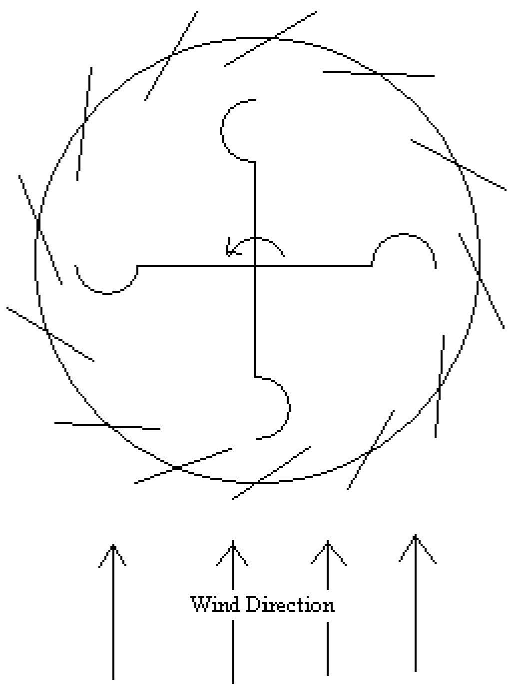

Figure 2 – External Surface of VAWT

Design Concept #2 - Horizontal Axis Wind Turbine (HAWT)

Design for the Horizontal Axis Wind Turbine includes substantial aerodynamic considerations. This is because the rotation of the blades is based on lift forces generated through the lift coefficient. Lift turbines use an airfoil shaped blade to increase velocity and efficiency. In the case of only using drag turbine blades; wind simply pushes against a slanted blade to create mechanical energy. The preferred concept for a HAWT system is an angular cut made on a specific pipe length that will simulate an airfoil shape. This airfoil shape will create a slight lift profile to cost effectively increase efficiency. Figure 3 is a basic example of a HAWT that could be developed for the project. A similar method of belts, or gears will be incorporated to increase the rpm from the turbine to the alternator, which is represented by a box-like shape on figure 3.

The advantage of using a HAWT is the higher efficiency due to the greater rotational speed that can be achieved. This allows for a smaller system than the VAWT, which will meet power requirements while at the same time decreasing the amount of parts and cost. However, a HAWT needs to be facing directly into the wind in order to obtain maximum efficiency and in order to accommodate for the added degree of freedom; an active control system or a stabilizing tail fin will be required. An active control system increases both the power consumption as well as the price of the system, therefore, leaving the stabilizing fin as the optimal choice. Another disadvantage of using a HAWT system is the direct disruption of the natural wind flow field, in the case that multiple wind turbines are constructed.

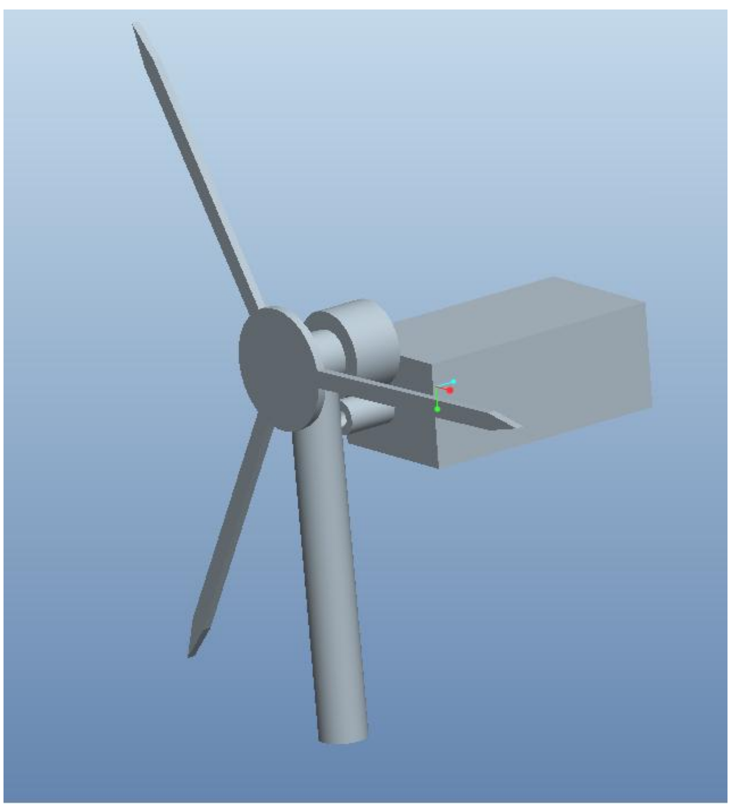

Figure 3 – Horizontal Axis Wind Turbine (HAWT)

Design Concept #3- Hydroelectric Generator

Hydroelectric power production is the method of harnessing the energy of flowing water to create electricity. In 2005, hydropower accounted for 96 percent of the renewable power generated in the US. In 1920, it accounted for over 40 percent of the nation's total electric supply. This is due in large to the fact that water is one of the world's most abundant resources and can be manipulated with a minimal amount of infrastructure to create a renewable source of energy. With this in mind, our third design concept is to build a hydroelectric generator that can be used by a single family which has a readily available supply of flowing water.

The hydroelectric generator will convert the kinetic energy of the flowing water into rotational mechanical energy through the implementation of some type of paddle wheel, or turbine. If a paddle wheel is selected for this design, and depending on the location chosen, a wheel constructed of light weight and durable bamboo could be used. This would cut down on the unit price of the product by using a sustainable resource that is present in many third world countries. A bull pulley connected at the opposite end of the rotating shaft will spin the pinion pulley attached to the alternator, as illustrated in figure 4. The gear ratio between the belt driven pulleys will depend upon the incoming flow rate of the water, inertia of the system, resistance from bearings, and the required rpm of the alternator.

Furthermore, the 12 volt direct current from the alternator will be stored in a battery with a minimum capacity of 300 W*h. The battery will most likely be of the automotive variety which is capable of storing the necessary. These batteries are naturally abundant in most junkyards. While the individual cost of these used batteries is high, a bulk purchase will lower the cost significantly. Also, certain measures will need to be taken to prevent water from coming in contact with the charging system. One way to accomplish this would be to use the insert for a car trunk as a type of shroud to protect the electrical components from water splashing back from the paddle wheel.

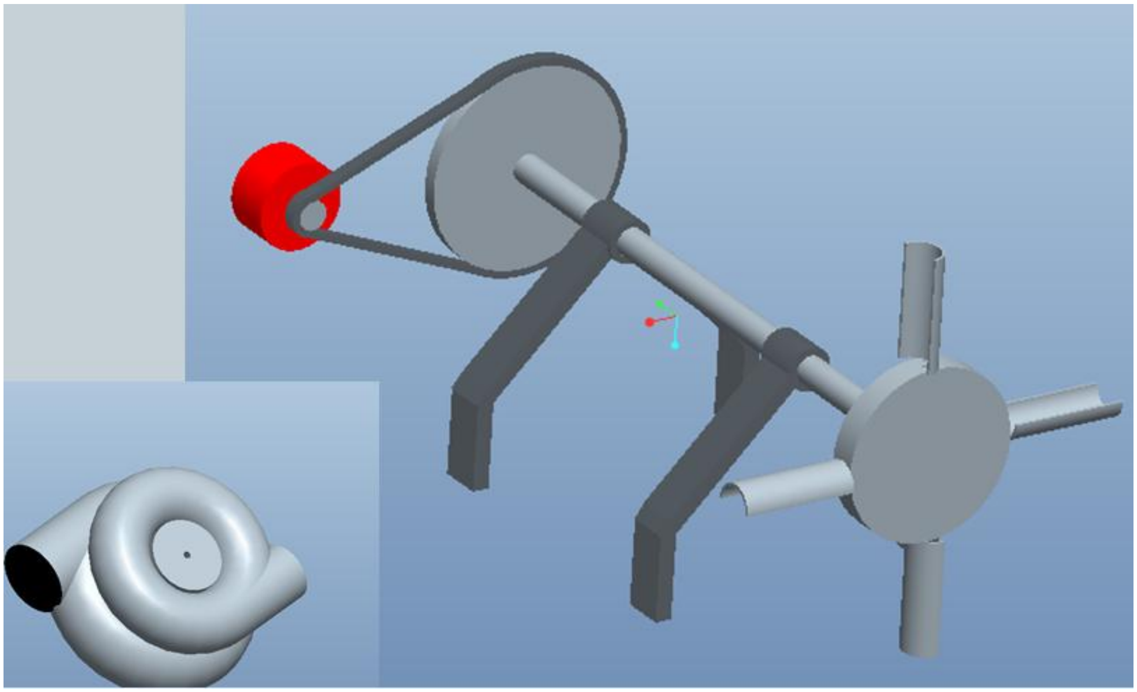

Figure 4 - Illustration of a potential prototype to generate hydroelectric electricity. The turbo pictured in the bottom left corner could be interchanged with the paddle wheel in situations where water is flowing from a pipe or channel.

Design Concept #4 – Tesla Turbine

The Tesla Turbine was initially designed by Nikola Tesla and works under similar principles as the previous designs. A working fluid imparts upon the turbine rotational mechanical energy, which is converted into electricity using an alternator. Figure 5 is a basic Tesla turbine design, with half of the casing cut out in order to see the internal working parts. There are four discs spaced apart and mounted on a central rotating axis, which is the mechanical output of the turbine. Water will enter the turbine at the top rectangular section and will rotate around the case between the discs until it slows and is pushed through the center exit area. This flow will induce rotation of the discs due to the friction effect between the water and discs. It is imperative that the flow remain laminar throughout the turbine until the exit point as this will maximize the friction and rotational speed.

Compact discs (CDs) have been found appropriate for use as the rotating discs in the system. This is due to the acceptable friction coefficient between water and the plastic used. It is also convenient due to the shape and size of the CDs. It is also essential to keep low rotational speeds, which is important as access to fast-flowing water will be difficult.

Another great advantage of using this system is that the price of parts required is much lower than the competing designs. However, the material strength of the CDs may be low during operation, and a method of controlling the rotational speed may need to be included.

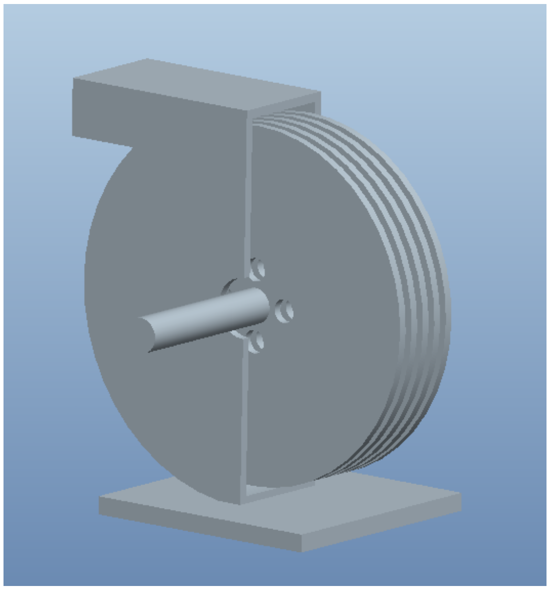

Figure 5 – Tesla Turbine CD Case

Decision Matrix

Table 1 – Current Decision Matrix

		Concepts							
		VAWT		**HAWT**		**Hydro-electric**		**Tesla**	
Specifications	**Weight**	Rating	Weighted Scores	Rating	Weighted Scores	Rating	Weighted Scores	Rating	Weighte d Scores
Durability	15%	3	0.45	4	0.6	3	0.45	1	0.15
Efficiency	20%	3	0.6	4	0.8	4	0.8	3	0.6
Ease of Assembly	15%	5	0.75	2	0.3	2	0.3	4	0.6
Low Cost	30%	4	1.2	3	0.9	2	0.6	4	1.2
Low Maintenance	15%	4	0.6	4	0.6	4	0.6	2	0.3
Innovative	5%	2	0.1	2	0.1	3	0.15	5	0.25
	Score	**21**	**3.7**	**19**	**3.3**	**18**	**2.9**	**19**	**3.1**

Table 1 shows a decision matrix based on theoretical research and basic intuition of the concept designs. As can be observed, the cost and efficiency were set to be the top two priorities in the project at this stage. However, during a teleconference with the customer, a different perspective was suggested, where cost, availability, and ease of assembly would be the most important criteria. The efficiency is not as important as long as the objectives are met, because the energy is essentially of infinite amount. The overall ratings at this point are similar and this trend is expected to change as a detailed analysis of the concepts is performed in the next deliverables.

Future Plans

There will be meetings with the customer every two weeks to present the progress of the project. The meetings will include all team members, mentor, and advising professors are also invited. Preparation for the next deliverable will require knowledge of available recycled materials, and extensive energy conversion research to accurately analyze each concept. At this particular stage the best concept was found to be the VAWT; however, this is very likely to change with the acquirement of additional data and resources. Concept selection will take into consideration all the deliverables that have been completed prior to that step, and after it has been established, construction and testing will be performed. The final product is projected to cost under $50 and must demonstrate it has satisfied all the objectives.

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