Design for Manufacturing, Reliability, and Economics

Team 7

Personal Hydroelectric Generator

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1 Introduction

There is currently a need for personal hydroelectric generators (PHEG) in the current market. These generators convert organic kinetic energy from the flow of rivers to produce a top necessity, electricity. This entrepreneurial project was proposed by Shane Radosevich who is the current Team Leader of this senior design group. The faculty approved the idea and the entrepreneurial faculty advisor became the sponsor for the development of this idea. The current small-scale hydroelectric generators do not produce enough power necessary for a comfortable camping trip or use in third-world countries. Therefore, the goal is to fill this void and design and build a personal hydroelectric generator that is affordable and produces a sufficient amount of power.

2 Design for Manufacturing

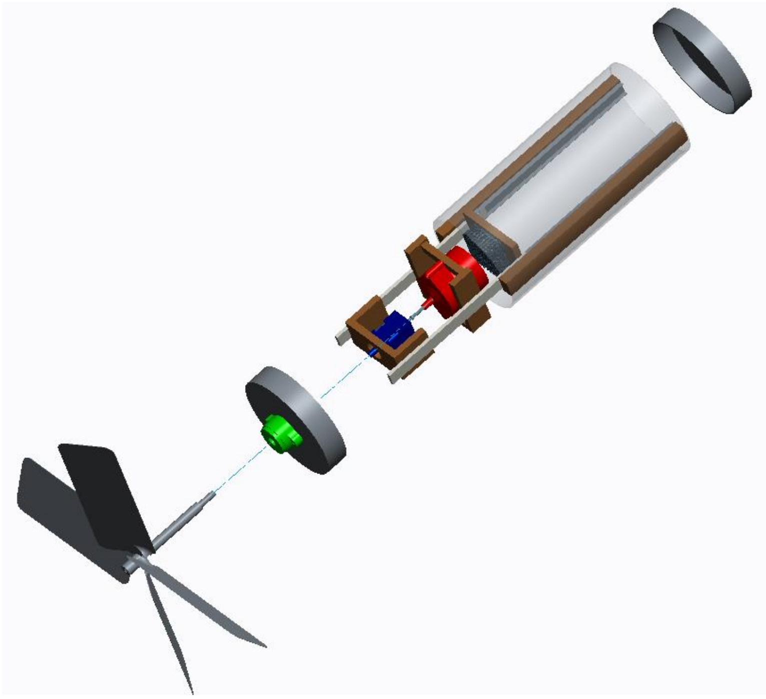

Figure 1: Exploded View of PHEG

Manufacturing of the components for this project are dealt with through third party companies. Once all the parts where obtained it becomes a logical method of assembly. The parts are listed as follows:

1. PVC housing, and end caps
2. Sliding rails
3. Wood-for mounting internal components
4. Gearbox
5. Alternator
6. Charge Controller
7. Shaft and coupling mechanism
8. Water-proof bearing on front end cap
9. Turbine Blade
10. Wattmeter
11. Electrical Wiring
12. Conduit to protect wiring

Once all of these parts are obtained, the manufacturing procedure used by the senior design team can be laid out in a simple to follow step by step process.

1. Obtain the PVC housing and drill holes equally spaced on the sides to mount the sliding rails.
2. Mount the sliding rails onto the housing by lining them up and screwing the rails in place where the holes are.

3. On the top of the PVC housing a hole is drilled, this is where the wiring and conduit will go.
4. The housings for the gearbox, alternator, and charge controller are assembled (For the prototype these are made out of wood). These housings will all be mounted onto the rails.
5. Once the housings are constructed, the alternator, charge controller, and gearbox are mounted to their respected housings.
6. The guide rails are extended out and the components are mounted appropriately. With the turbine at the front of the system, the charge controller is in the back, alternator in the middle, and gearbox in front
7. Wires attached to the output of the charge controller should at this point be extended through the opening previously made at the top of the housing.
8. All the shafts for these components need to be manufactured to fit properly to couple the gearbox and alternator together.
9. The front end cap should be drilled to fit the shaft diameter, holding the turbine on the outside.
10. Two holes need to be drilled equidistantly on the sides of the front end cap hole for the waterproof bearing to be mounted.
11. Then, the main shaft is affixed through the hole of the front end cap and coupled to the gearbox.
12. Here the front end cap is fixed onto the housing and sealed.
13. The water-proof bearing is now placed over the shaft on the outside of the end cap to water-proof the product.
14. Now the turbine is affixed to the exterior part of the shaft.
15. Next, the conduit protection is set over the protruding wires to secure and water proof the exterior of the device.

16. The wattmeter is separate and should be manufactured with proper plugs to attach the protruding wires on land.
17. The wattmeter has leads which are connected to a battery; the product is complete.

About five to six months were needed in order to complete the research and determine which components were best for the product. Assembly time was relatively quick. In about a week of all the parts being received, the device was put together. The PVC housing and end caps were drilled with their required holes in one day. In that same day the guide rails were attached. Construction of the housings for all the internal components were also done in one day. With proper measurements, the two shafts needed for the prototype were constructed by FSU's machine shop in a day as well. Promptly, the prototype was finalized when these shafts were received. By the next day, all pieces were put together and the prototype was complete.

The complexity of the design is fairly simple. There is not much in the design that would be deemed unnecessary. Every component has a needed function. However, given more time and research, it is probable that some components of the design should be replaced. The alternator and gearbox have startup torques that are not optimally small. This added force that the flowing water needs to overcome is not ideal and better components can be chosen to improve the devices production. Also, the turbine was chosen merely for its availability and does not have optimal characteristics. There are better turbines that can be used with optimal pitches to grasp more energy from the flowing water. It would not be necessary to add or remove parts, only optimize.

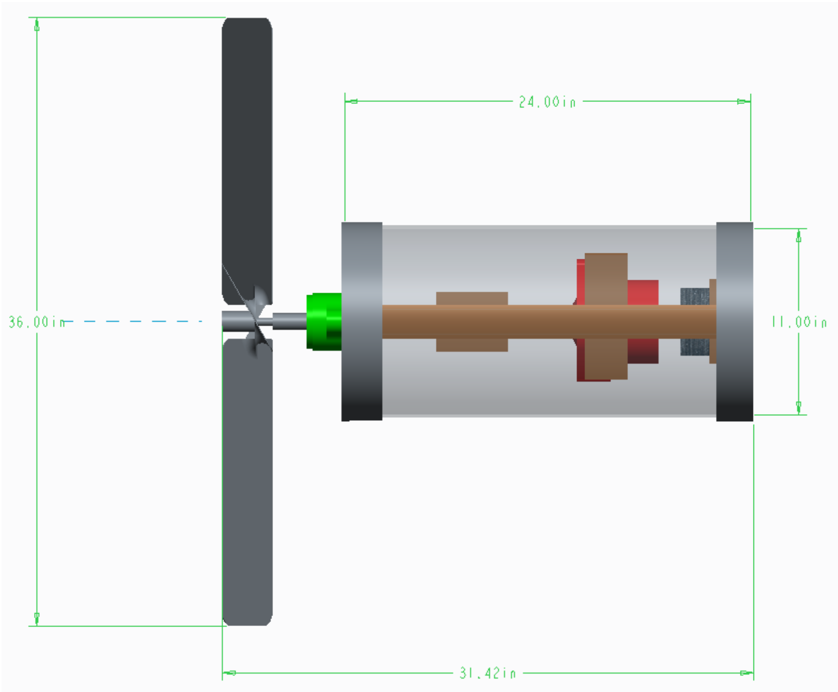

Figure 2: Dimentional View of PHEG

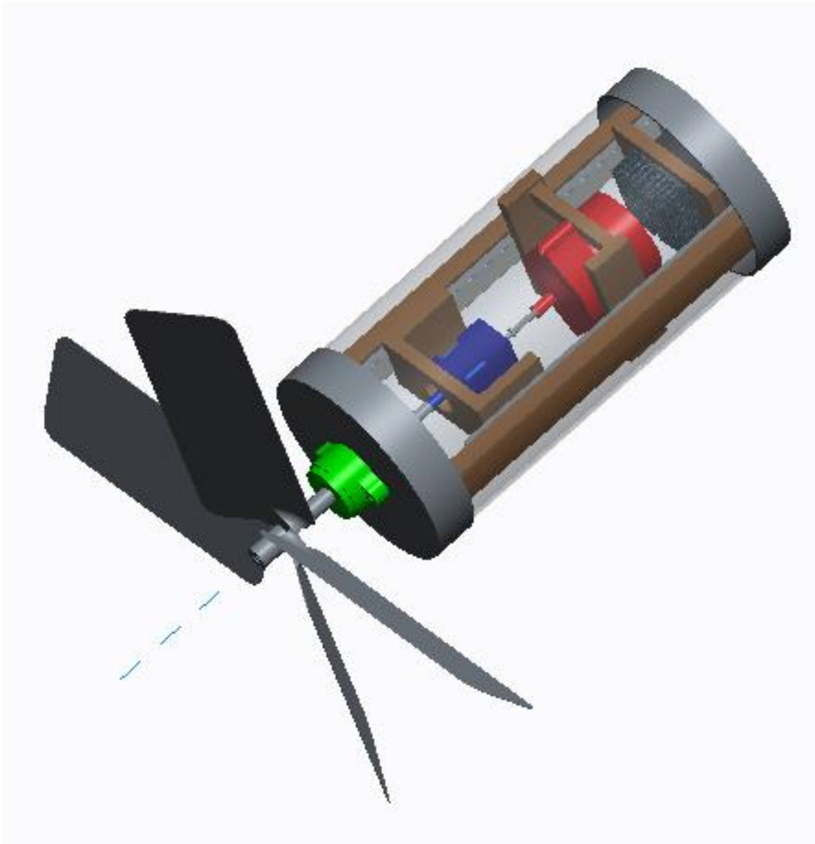

Figure 3: Tilted View of PHEG

3 Design for Reliability

In the coming week, the device will be ready for testing and the team will begin to be more suited to answer questions about reliability.

There are a number of things that will be looked at for reliability testing; the most important being waterproofing. With ample amount of sealant in every crevice and a failsafe sponge put into the housing, the device should be able to stay fully submerged in water over long periods of time. After initial testing, how well the device does in avoiding any type of water damage is important.

Next, the device will have to be looked at mechanically to see how the components do when under the actual conditions of a flowing body of water. The speed of the turbine determines the power production of the rest of the machine. Thus, the team needs to see how fast the turbine will spin when placed in water, as well as any components not accounted for previously which would affect the turbine's performance. For example, will the turbine spin hard and fast enough in the water to compensate for the starting torques of both the gearbox and alternator? Will the water have enough force to spin the turbine on its own at all? These are questions the team needs to look out for to determine reliability.

Electrical components will be looked at in initial testing to see how much power the device is producing in real world application. It is important for the team to gather electrical data to see if the device is even experimentally worth using. Does the power production exceed the minimum required for keeping a handful of LED lights running for hours on end? Is the production constant, or does it decrease over time? Does internal resistance in the wiring affect the power production, or is it negligible? These are questions the team needs to address from an electrical standpoint to determine how the device will fair electronically.

Once the preliminary tests are run, it will be possible to determine what kind of longevity the device will see.

Since PVC is used for the housing, it is anticipated that the device will last the test of time. Water will not rot the PVC and fresh/salt water will not affect the durability of the PVC. Because of this, our product will be able to withstand significant abuse and last years with maintenance. Below is the Failure Modes and effects analysis in a more organized matter.

Table 1: Rating for Failure Mode Analysis

I	No relevant effect on reliability or safety
II	Very minor, no damage, no injuries, only results in a maintenance action (only noticed by discriminating customers)
III	Minor, low damage, light injuries (affects very little of the system, noticed by average customer)
IV	Moderate, moderate damage, injuries possible (most customers are annoyed, mostly financial damage)
V	Critical (causes a loss of primary function; Loss of all safety Margins, 1 failure away from a catastrophe, severe damage, severe injuries, max 1 possible death)
VI	Catastrophic (product becomes inoperative; the failure may result in complete unsafe operation and possible multiple deaths)

Table 2: Failure Mode Analysis for Personal Hydroelectric Generator

Function or Process Step	**Failure Type**	**Potential Impact**	**Severity**	**Potential Causes**	**Occurrence**	**Detection Mode**	**Detection**	**RPN**
Housing Function: Waterproof and protect internal components from the elements	Crack in housing, water failure	Fry and destroy all electrical components	VI: device becomes inoperable	Animal or debris impact	0-1	PVC should be strong enough to handle destruction in fresh/salt water, sealant is amply set	0-1: very easy to detect	80
Turbine Process: Turbine should be able to spin the shaft to generate electricity	Turbine becomes separated from shaft	The product becomes incapable of generating electricity	V: Machine becomes inoperable	Animal or debris impact	0-1	Turbine is set on the shaft as tightly as possible, detection would be seen by zero generation of electricity on wattmeter	0-1: Very easy to detect	10
Exterior Wiring function:	External wires to battery become ripped and damaged	Electricity cannot be produced and stored, possible electrocution of wildlife	IV: Possible electrocution may occur	Animal or debris impact	1-2	Durable conduit used to protect the wiring	1-2: Easy to detect	5
Internal component failure	Internal components become wet or damaged	Product will not work at all	IV: Product becomes inoperable, parts are replaceable	Housing failure	0-1	Electricity will seize to be produced	2-3: Not so easy to detect a water leak before it happens	5

Table 3: Failure Effects Analysis for Personal Hydroelectric Generator

Recommended Actions	**Responsibility**	**Target Date**	**Action Taken**	**Severity**	**Occurrence**	**Detection**	**Risk Priority Number**
Water absorbent sponge to prevent immediate catastrophe, Housing has to be sealed impeccably at all points of possible leak	The senior design team	Immediately	Double check and reinforce all seals	V: Device can leak slightly before complete failure	0-1	0-1	80
Double check and possibly keep a spare turbine	The senior design team	After preliminary testing	Reinforce joint between turbine and shaft	IV: Turbine failure deems product inoperable	0-1	0-1	10
Additional conduit layer on top of existing one	The senior design team	After preliminary testing	Double layer the wiring conduit	IV: Possible electrocution may occur	1-2	1-2	5
Reinforce the housing	The senior design team	After Preliminary testing	Reinforce and double check all joints of the housing	V: If components fail, the device is inoperable	0-1	0-1	5

4 Design for Economics

In the recent generation, a shift has in the traditional way people obtain energy has taken place. While the integrated central power grid still supplies the majority of the energy consumed, other methods are now available. With the rise in popularity of the clean energy movement, a new untapped market has formed. The demand for clean micro-power generation technologies like solar and hydro has significantly increased. The challenge is in creating marketable means over supplementing or satisfying the consumers energy needs. The Personal Hydroelectric Generator (PHEG) was the design team's response to the challenge.

4.1 Cost Breakdown (Proof of Concept)

The total cost of the PHEG was $1568.47. A breakdown of the individual components can be seen in the pie chart below. The large majority of the cost was incurred from the waterproofed housing. The waterproofed housing accounted for roughly 40% of the total cost. The rest of the costs were divided between the different mechanical and electrical components.

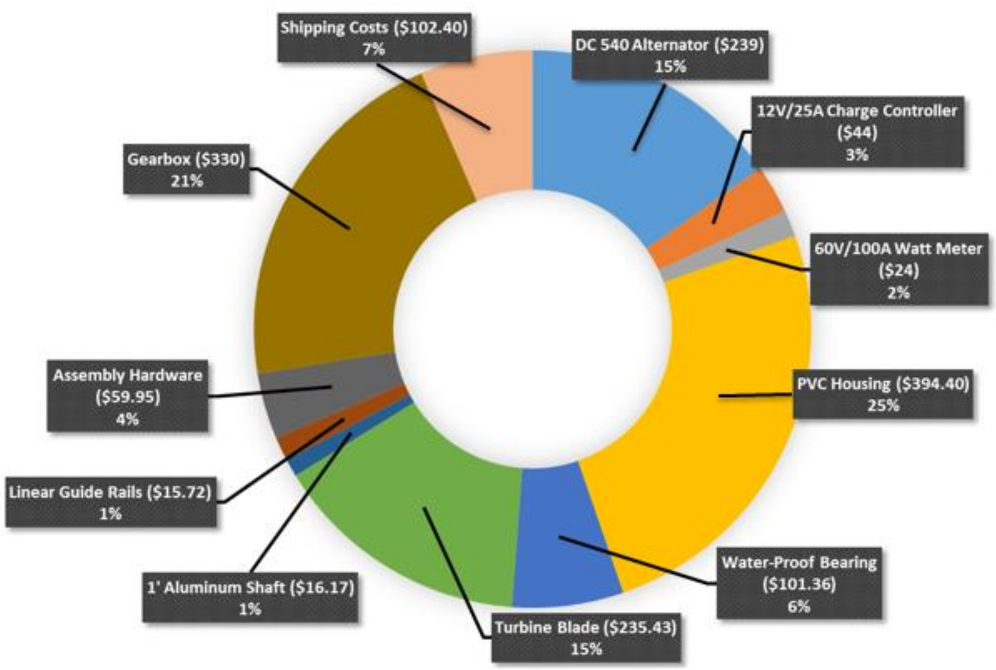

Figure 4. Cost Distribution of Project

The project constructed was a proof of concept and only used for demonstration, with optimization of material selection as well as manufacturability the cost here could be reduced significantly. Upon commercialization and distribution on a larger scale each component will become cost efficient, resulting in a cheaper product.

4.2 Comparative Comparison

Since the portable hydro-power market is relatively new, there was not much information about competition being sold commercially online. However, two concepts were found online still in developmental stages. The first competitor was the Hydrobee, which is a very small USB charging station about the size of a soda can, it provides enough power to charge a cellphone. The other competitor was a portable hydroelectric generator developed by a company called Bourne Energy. This generator was in comparison to the size of the PHEG but doubled in cost. The estimated power output, cost, and weight found online for these two products were compared to those of generated by the PHEG proof of concept as well was those estimated once optimized and commercialized. The graphs below show the power outputs for each generator normalized by the cost to create it and the weight of the designs. The design created by the senior design team, while lowest in this analysis, still was comparable to the other two concepts and has much room for improvement with optimization as seen by estimations seen in the fourth column of the graph.

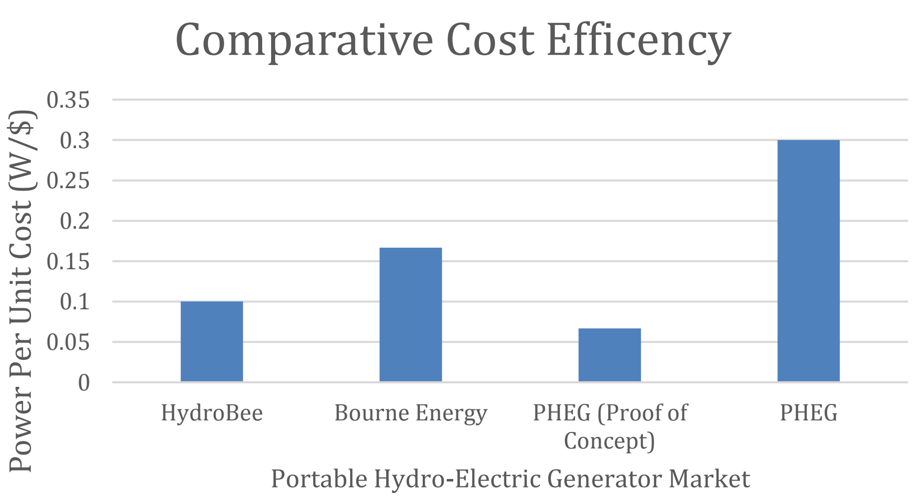

Figure 5: Power and Cost Ratio of Comparable Products

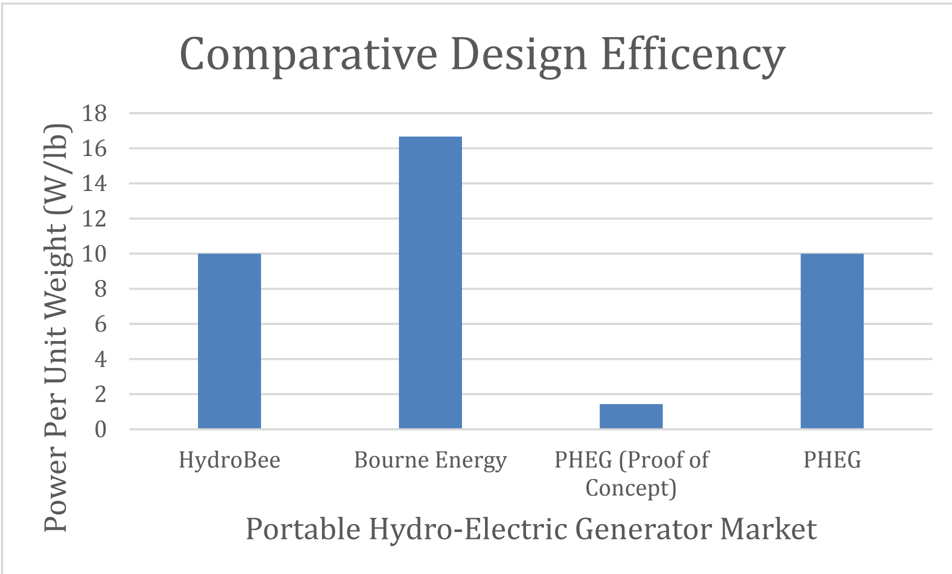

Figure 6: Power and Weight Ratio of Comparable Products

5 Conclusion

This team has been tasked with developing and marketing an effective method of getting clean electricity into remote areas. For the environmentally conscious outdoorsmen, hydroelectric energy can be an appetizing alternative to burning fossil fuels. Currently, the only viable way of producing hydroelectric energy is by installing permanent fixtures that can be costly, labor intensive, and damaging to the environment. To keep on task through the semester a Gantt chart was used to guide the team through the majority of the of the project, and all components have been designed into a final CAD file. Upon the completion of the semester, the team has manufactured and assembled a portable and personal hydroelectric generator.