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April 20, 2012

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
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Re: ENSC 440 Post-Mortem for a Rain and Solar Power Generator

Dear Dr. Rawicz:

The attached document, *Post-Mortem for a Rain and Solar Power Generator*, outlines the design and implementing for our project for ENSC 440 (Engineering Science Project). Our achievement is to design and implement a power generator which can create electricity for sunny and rainy weather conditions. Our project uses green energy which will cause no effect on nature.

Our post-mortem document provides the current state of our product, deviations from plans, future plans, budgetary and time constraints. Lastly, individual team members will reflect on their experience of group dynamic and technical knowledge gained while working on the project

Green Power Innovation consists of five skilled, hard-working, and talented fourth-year engineering students: Frank Feng, Zhiyu Hu, Max Liu, Jeff Bian, and Xiao Dong. If you have any questions or concerns about our design, please feel free to contact me by phone at (778) 996-5591 or by e-mail at ffa5@sfu.ca.

Sincerely,

Frank Feng
President and CEO
Green Power

Enclosure:*Post-Mortem for a Rain and Solar Power Generator*

2012

Post Mortem for a Rain & Solar Power Generation System

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Submitted to: Dr. Andrew Rawicz - ENSC440

Stephen Whitmore - ENSC305

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Table of Contents

List of Figures

Glossary

GPI	Green Power Innovations
ISO	International Organization for Standardization
OSHA	Occupational Safety and Health Standards
RSPG	Rain and Solar Power Generator

1 Introduction

Our company is developing a renewable energy generator (RSPG). The device will collect the raindrops and sunlight to produce electrical power. The system will be highly effective in all space and climate [1]. Members of GPI have been working closely on developing, integrating and testing RSPG for the past 4 month. This document will provide the most current state and the deviation in design of RGPG prototype, the issues encountered along the development process, as well as the future developments for RSPG.

2 Current State of System

Green Power Innovation has been pursuing a Rain and Solar Power Generator (RSPG) prototype system which will harvest solar energy and the potential energy of rain drops to provide proper power. The RSPG system will continuously operate when user turns on the system and also switch between rain mode and solar mode.

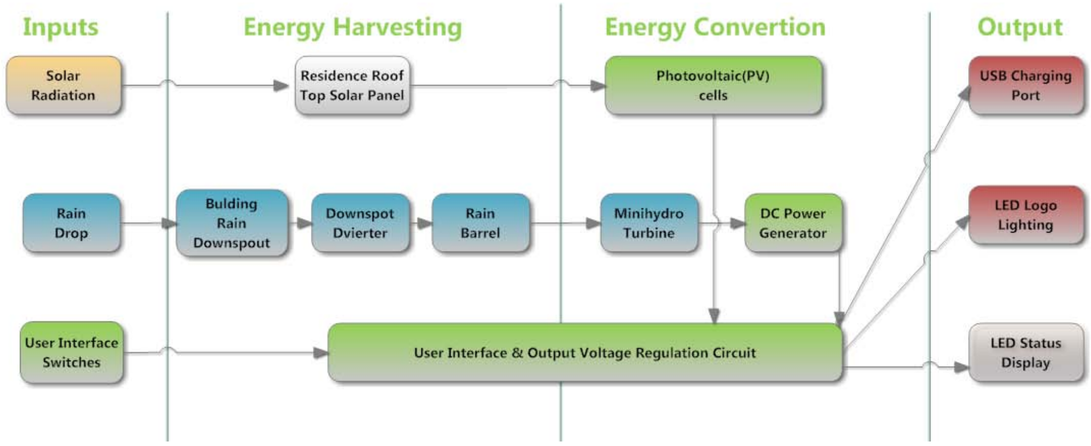

Figure 2.1: System Block Diagram

Figure 2.1 provides a high-level design of the system prototype and demonstrates the process how rain & solar energy convert to electrical energy.

Each block in Figure 2.1 represents either a physical part or a sub sub-systerm of the prototype. The arrows between blocks represent co-operations between sub-systems.

If solar power mode is selected, the solar panel, which was mounted on roofs with removable mounting locks, will start electricity generation within 10 minutes when solar radiations waves directly hit the solar cells. The solar mode status LED light maintains "on" unless user switch off the entire system or select other mode.

If the rain mode is used, the system will automatically harvest rain drops thought the rainwater from the building downspout into the rain barrel and start electricity generation automatically once the water level in the rain barrel reached optima power generation level (carefully calculated and design to obtain maximum power output. please refer to Rain Barrel section for detailed explanation). The Rain mode status LED light maintains "on" unless user switch off the entire system or select other mode.

The electrical power output is common to both modes though a same regulation & user interface circuit. Output power is connected directly on a LED lighting array (consists of 45 high power LED lights to form a "GPI" logo). An USB charging port is also attached, and user can sesclet using USB charging or local load (in this case "GPI" LED Logo) throught the output control switch.

2.1 Rain Power Generation System

The rain power generation system is consisted of two parts, the Minihydro Turbine Subsystem and a DC power generator. The Minihydro Turbine runner and DC power generator are screwed together though a screw shaft, so the rotor of the power generator will rotate with turbine blades without any idling.

The water injection head is connected with rain barrel's outflow pipe, and the injection line is fixed and tangent to the turbine blade through the upper injection hole of the shelter.

Turbine runner is made of a series of 12 spoons. The spoons are first circled together vertically, and then screw each of them on to two metal discs. Finally insert shaft nuts and glue them on to the metal discs as shown in Figure 2.

Figure 2.2 Turbine Runner

The spoon-shaped buckets ensure efficient momentum transfer of the water flow to the turbine wheel.

2.2 Solar Power Generation System

As the advanced technology for solar power generation already exists on the current market, this saved us a lot of time to do the research. The solar power generation system was not complicated. We didn't implement the DC to AC inverter because the maximum power delivered of the solar panel is 10 Watts [2]. Therefore, we decided to use DC voltage directly. The following figure shows how a solar panel works.

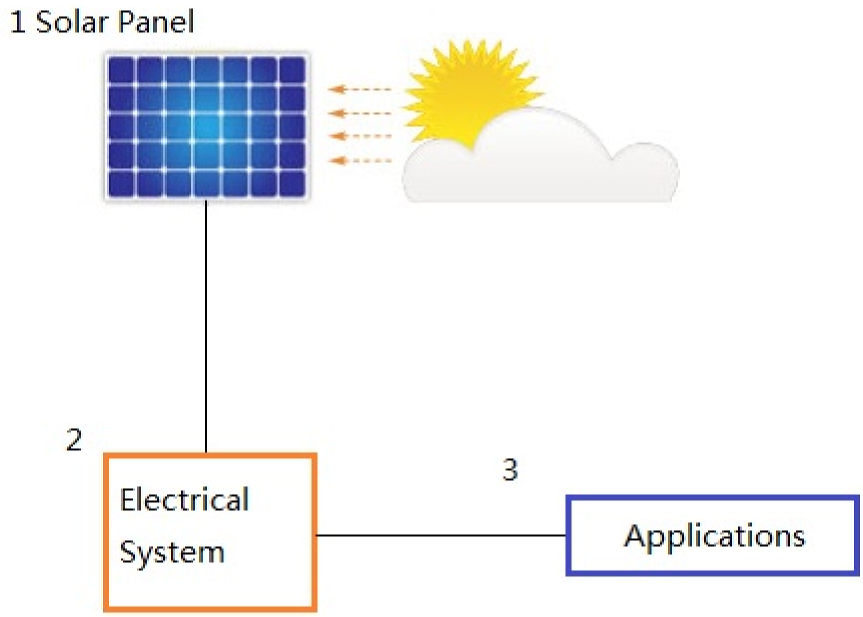

Figure 2.3: Solar Power Generation System

The electrical system consists of a voltage regulator that controlled the output voltage ranging from 3V to 37V. The Solar panel will be directly connected to the electrical system and then applied to the applications. Since the maximum voltage supply from the solar panel is 22V, we can use it for various applications, such as 9V battery chargers and so on. The solar panel we purchased can be used for at least 25 years and also water proofed. The purpose of adding the solar panel is to make sure our power generation system works in different weather conditions. We have put more effort in designing and building the rain power generation.

2.3 Electrical System

As we mentioned in the design specification, the key component of the electrical system is the LM317T adjustable voltage regulator since the user can adjust the output voltage to match the needs for various application, such as LED voltage supply and cell phone charger. The high-level electrical system is shown in the following figure.

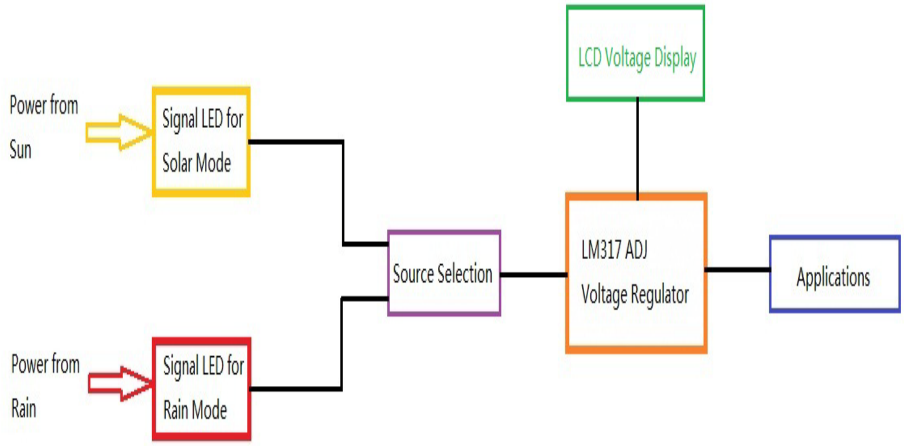

Figure 2.4: High Level Electrical System

As seen from the graph above, we can receive the power from both sun and rain and then select the one that we want to use. The corresponding signal LED will be on, indicating the source that we choose (yellow for solar mode and red for rain mode). The generated power will go through the LM317 voltage regulator. Depending on the magnitude of the generated power, user can adjust the trimpot to change the supply voltage from 3V to 20V. The output voltage will be displayed by the LCD so that user can tell how much voltage is generated at that moment. Finally, the DC voltage will connect to the applications. Due to the efficiency of the rain power generation, the DC power is limited up to 6V for the rain mode (it depends on the rotational speed of the turbine fan), however, it's enough to launch the LED signboard and USB cell phone charger. To select the source, we added a toggle switch to control the input and two LEDs to indicate the chosen mode. To protect the LED, we added two current limit resistors as over-current protectors. As we want to maximize the power supply, we bypass the signal LEDs to the LM317T voltage regulator in order to minimize the voltage drop across the LEDs and current limit resistors. In addition, two diodes were added to prevent current reversing to the voltage regulator. However, we still have approximately 0.6 to 0.7 voltage drop compared to the input, and this is due to the fact that the resistors associated with the voltage regulator consume the electricity. In a word, the circuit works as we expected from the design.

2.4 plumbing system

The plumbing system consists of a water tank and a long pipe. The water tank is designed and achieved according to the basic operation of toilet fulsh. The plumbing system takes the water input from downspout diverter and stores it in the water tank. The stored water can be then released either when it reaches the highest water level or by manually pulling the handle. The plumbing system will have the water output through a flapper on the bottom of the water tank and the long pipe connected afterward.

2.5 User Interface

The user interface hardware contains three switches, two Leds, one voltmeter, and one USB output. The following figure shows the user interface.

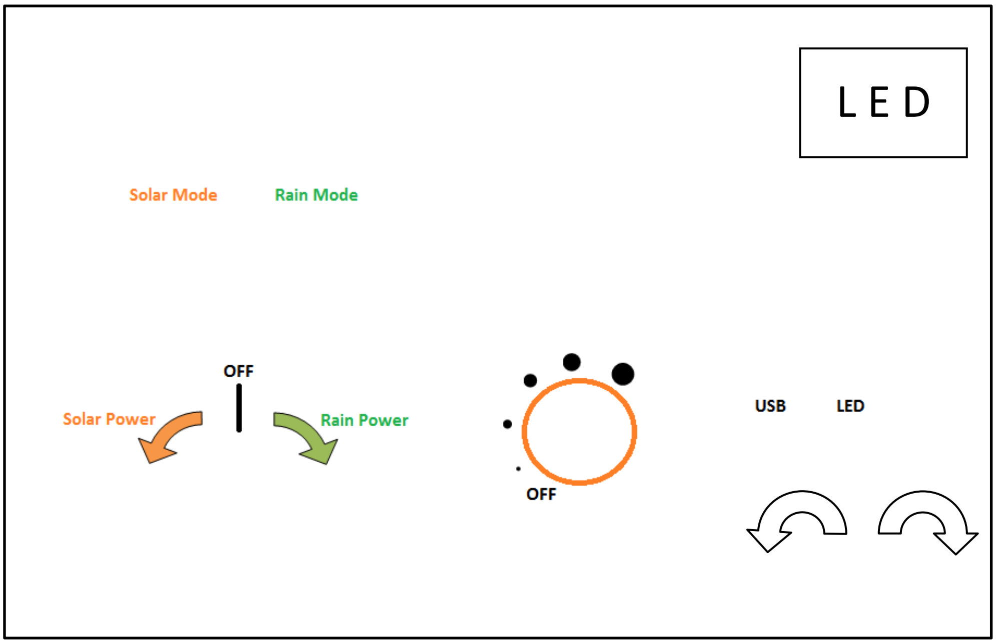

Figure 2.5: User Interface Schematic Diagram

Three switches are placed at the bottom of the user interface. The left bottom switch will adjust the power generation mode. If the user turns the switch to left, the system will work with the solar power generation and the solar mode LED will turn on. If the user turns the switch to other side, the system will work with the rain power generation and the rain mode LED will turn on. The middle switch can adjust the output voltage from 3V to 30V. The bottom right switch can switch between applications. There is also a USB port connected on the right side of the user interface.

2.6 Testing of the Prototype

We put most of the efforts on the rain power generator testing because it's the key feature of this project and has been completely designed and implemented without any reference from similar products. In addition, the specification of the solar panel is clearly listed on the product data sheet. During the testing process, the first testing result, including the magnitude of the generated voltage and power, is curial for the future improvements.

2.6.1 Rain Collection Testing

The following bar chart summarizes the rain amount of March 2012 in Vancouver, and the table represents the time spent for the rain barrel to reach its maximum level from the selected days of March 2012. To do this, we connected one side of the downspout divider, as mentioned in the design specification, to the downpipe and then connect the other side to the rain barrel.

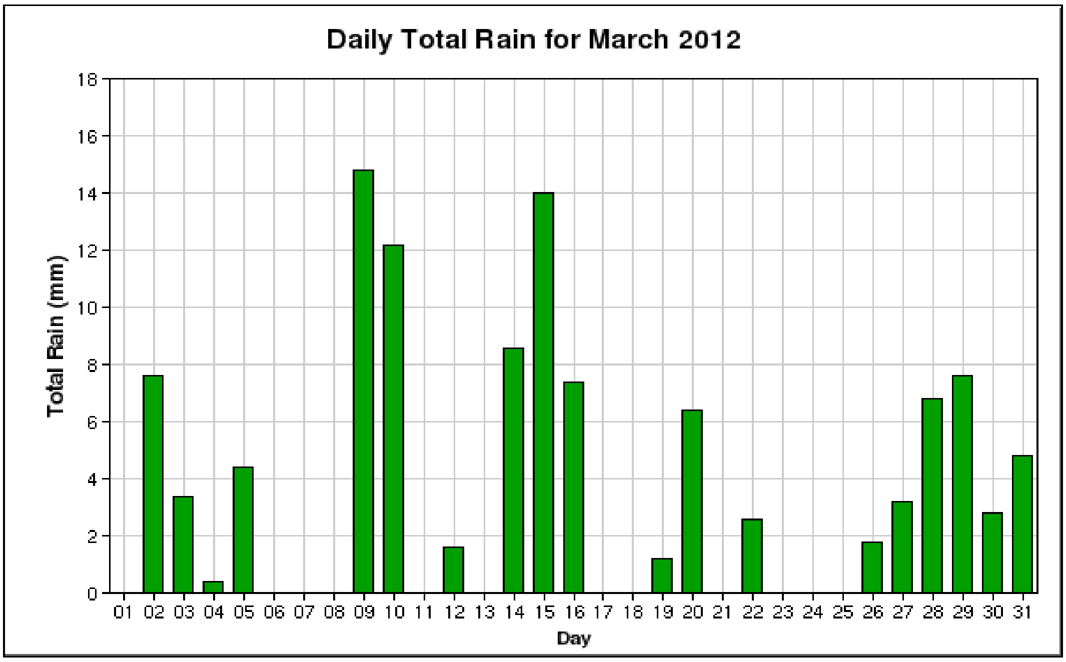

Figure 2.6: Daily Rain Amount of March 2012 in Vancouver [3]

Table 2.1: Time Needed For The Rain Barrel To Reach Maximum Level And Its Corresponding Maximum Output Power

Day	Time to Reach maximum water level (Hours)	Roof top area	Daily Rain (mm)	Expected Total Collected Water (m^3)	Theoretical Max Power Output Value (J)
9	0.5	100 m^2	15	1.5	150000
14	1	100 m^2	9	0.9	90000
16	3	100 m^2	8	0.8	80000
28	0.75	100 m^2	7	0.7	70000

2.6.2 Power Output Testing

The power output testing was done using the following method:

- Rain Barrel at maximum level (i.e. 50L)
- Rain Barrel at two different height (i.e. 5m and 10m)
- Flushing speed of water controlled by the time spent for emptying the rain barrel (i.e. shorter time meaning faster speed)
- Electricity production calculated by the product of the generated power and time

Table 2.2: Output Power Testing Data

Time	Height	RPM	Power	Electricity Production	Theoretical water potential	Efficiency
5min	5m	60	1.25 W	375 J	2500 J	0.15
10min	5m	50	0.99 W	600 J	2500 J	0.24
15min	5m	10	N/A	N/A	2500 J	0
5min	10m	150	3.5w	1050 J	5000 J	0.21
10min	10m	100	3w	1800 J	5000 J	0.36
15min	10m	70	1.5w	1350 J	5000 J	0.27

The best solution was obtained according to the highest efficiency, which is 36%. Therefore, we used 10 meters height and 10 minutes releasing time as our design parameters.

3 Deviation from the Original Design

3.1 Plumbing system

The plumbing system has not deviated much from original designs. The only difference is the size of the water tank has changed. Originally, we planned to have the water tank be a cylindrical shape with a radius of 50-70cm. However, it is better to have a cuboid shape since we need to dig holes on the side and flat surface is needed. Thus, we got the water tank with a size of 60cm * 46cm * 45cm.

3.2 Minihydro Turbine Subsystem

It is obvious from Figure 3.1 that both turbine runner and its shelter are alternated tremendously. Designed turbine runner will have 24 spoon-shaped buckets but we only capable make 12 spoons circled together. The runner cover is shaped into rectangle rather than circle in the original design. Especially in our project case, custom made plastic model from plastic fabrication company is beyond our financial budget and limited time schedule. Therefore our actual solutions are relatively cheap and functioned as expected.

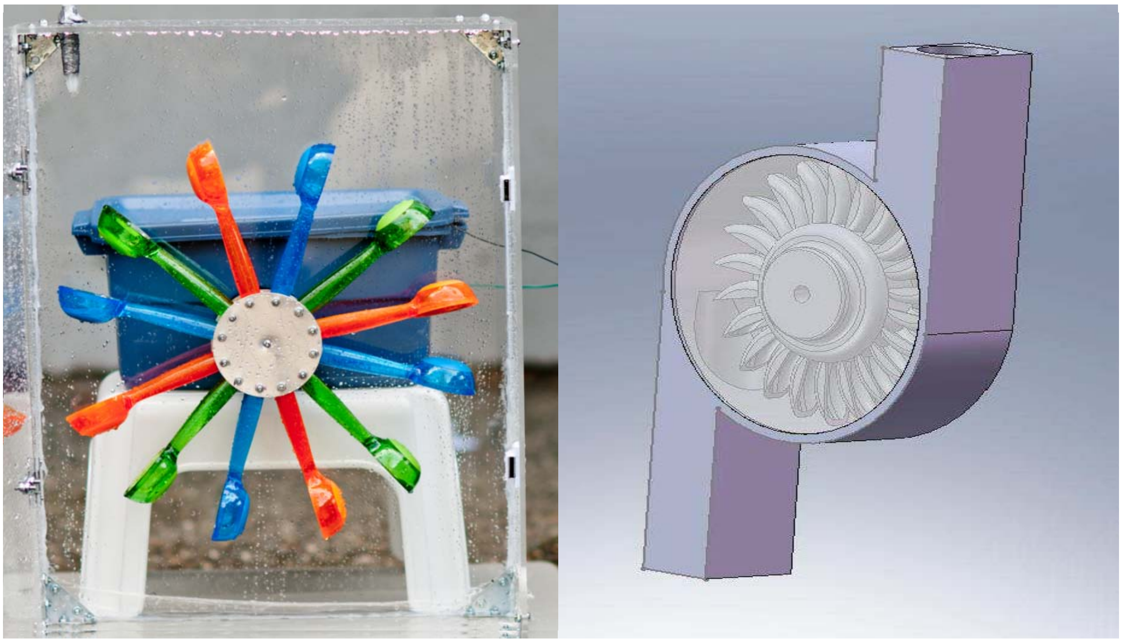

Figure 3.1: Actual VS. Designed Minihydro Turbine Subsystem System

3.3 User Interface

As we mentioned in section 2.4, we designed user interface by hardware. However, this is not the idea design as we planned before. The original design of use interface will use a microcontroller to program all functions. The user interface also will use a monitor panel to show entire system situations. Four pairs of buttons will directly control the entire system on and off situation, turn on or turn off the water tank outflow valve, switch the power generation mode and choose the output applications separately. Instead of rechargeable battery, we provide a USB port for user to choose what type of charging they want to plug in. Due to the limit time and budget, we are unable to build our user interface as original plan.

4 Future Improvement of the System

The main goal for solar and rain power generation system is that we focus on green engineering. The entire system utilizes natural resources to generate electricity. Our entire system still has lots of future improvements to achieve a higher efficiency and lower costs. We believe that the future improvement will make our product more competitive on the market. The product will not only focus on family use but also for the industry area. The following sections will explain more details for our future design.

4.1 Turbine Runner

For massive production, it is better to build a customized turbine runner which is exactly as our designed solution to increase energy conversion effieiency. As well as reduce defection of DC power generator due to centrifugal motion.

4.2 Water Filter

The current raindrops will be directly drained after flushing the turbo fan. At the beginning of our design, we want to collect the water flushing the turbo fan. The raindrops can become potable water for human use after point-of-use filters. Due to limitation time, we cannot finish this task before final demo. The water filter procedures are also very strict and complicated. Hence, we decide to apply this function in the future.

4.3 User Interface

Currently our project's user interface is a hardware design. The idea user interface should use a microcontroller to program all functions. The user interface also will use a monitor panel to show entire system situations. The monitor panel will display the instant output capacity, the battery storage capacity, current power generation mode, current used application, as well as error messages. Four pairs of buttons will directly control the above functions separately. This future improvement will make the user interface much simple, obvious and more convenience.

4.4 Plumbing System

Add a water level sensor.By having water level sensor in the water tank, we can display the water level through the user interface and the user is able to better decide when to use the rain water.

A larger and stronger water tank By having a larger and stronger water tank, more water can be stored and more flexibility is available for the user.

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5 Budgetary and Time Constraints

5.1 Actual and Estimated Project Timeline

The timeline chart has the expected time for completion in purple and actual time for completion in red.

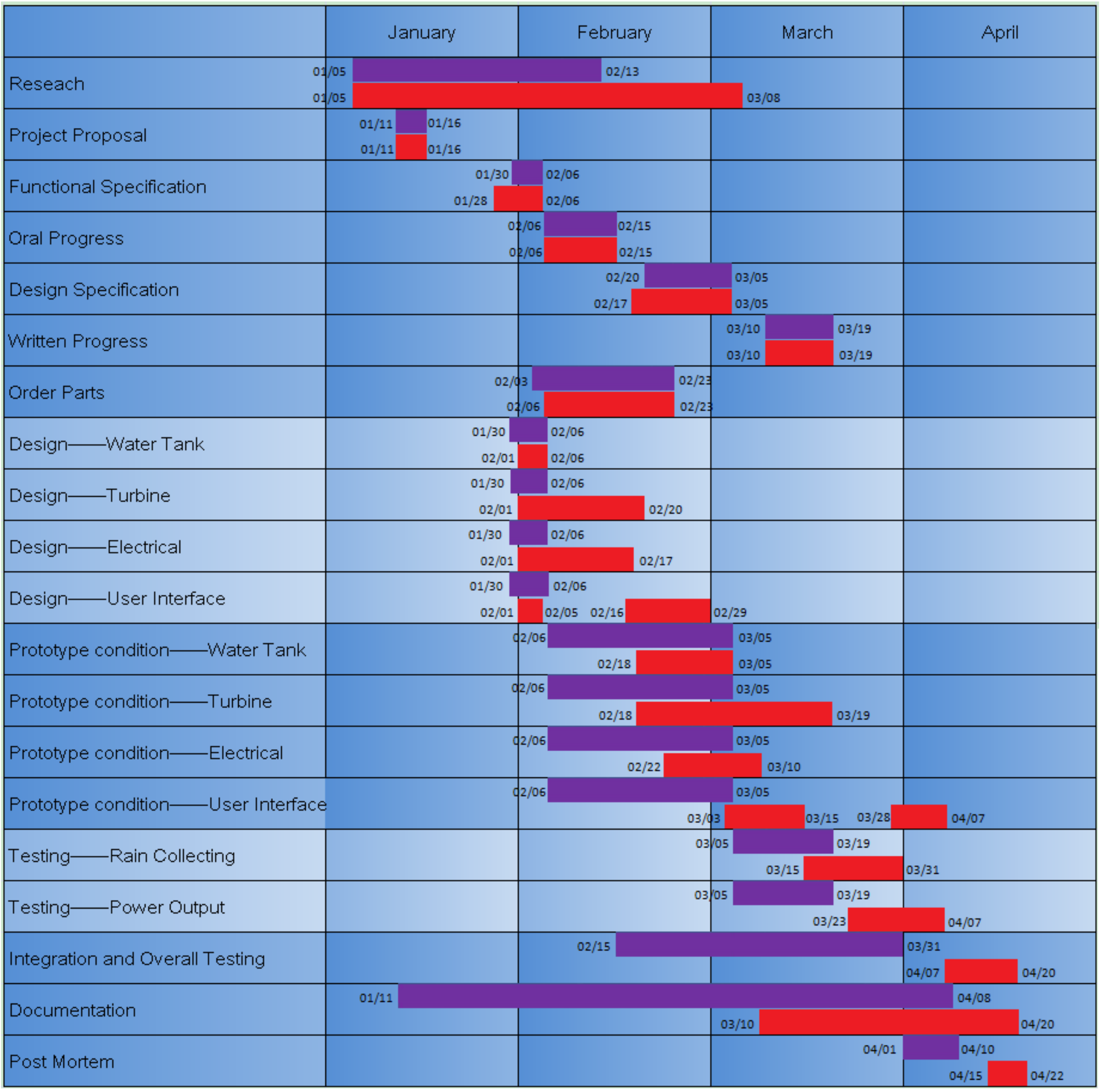

Figure5.1: Gantt Chart of Project Tasks

As we can see from the chart, we spent more time on researching because we made some changes to our design and more research was needed for the new changes. Notice that we have spent more time than expected on functional specification and design specification. One reason is that we are all not native English speakers and it took us a lot of time writing, which means that we had to start earlier on them. We were able to start design process as scheduled, but some parts of design took longer time than expected as they were more complex than we thought. At the same time, we started to order parts needed.

Due to the exam conflict and design specification, we started to build each module half month to one month later than expected. When it was the time near the end of prototype condition period, we were able to start testing the major function of the project. After all, the whole integration process had been delayed for more than one month and it is about to be completed by April 20, 2012. Also, we took the suggestions from the TA, to put less emphasis on documentation. Thus, we started documentation much later than scheduled and finished it by April 20, 2012. Lastly, post mortem was delayed by half month and completed by April 22, 2012.
We have learned that it is better to start early than start late. Also, better schedule should also take the consideration of exam conflict.

5.2 Actual and Estimated Budget

The initial estimation of the project budget as of the proposal is summarized as below:

Equipment List (Include brand and model # if possible)	Quantity	Estimated Unit Cost
5W5 Watt 12V Flexible Solar Panel Charger(ICO-SPC-5W)	4X $28.49	$113.96
High Performance 2-Piezo Layer Bending Elements(T215-A4CL-103X)	5X $44	$220
Turbo Fans & Gears	-	$30
High Power Low Speed DC Generator Motor	1	$245
Rain Collector and other parts	-	$50
Duracell AA Rechargeable NIMH Battery	4X 2.5	$9.99

Cables and other electronic parts	-	$40
Water Filter System	-	$100
Total Cost		$808.95

Table 5.1: Initial Estimation Of Solar & Rain Power Generator

As shown in the above table, the DC power generator and the solar panels are the core parts of the project. The other components could change during the design process. The table below summarizes the final cost of our project.

Equipment List	Quantity	Price
10 Watt Solar Panel 12V Battery Charger	1	$53.98
High Power Low Speed DC Generator Motor	1	$245
Turbine Fans & Gears • Spoons • Metal Disc	 • 12 • 2	$20 • $20 • Borrowed
Electronics Parts • Enclosure • Toggle switches • LEDs • LM317T • Diode-signal 10/PKG	 • 1 • 2 • 1 • 2 • 1	$29.22 • $17.24 • $5.89 • $1.49 • $3 • $1.60
Rain Collector • 79L TOTE • Valve • Tank Lever • FLX CP15X125 • Float Ball • FLX CP 2X1.5 • Reduc Adapt • 1 1/4 CPLING	 • 1 • 1 • 1 • 1 • 1 • 1 • 1 • 1	$59.34 • $11.99 • $9.99 • $5.79 • $7.99 • $5.79 • $7.99 • $2.36 • $1.08

Turbine Fan Shelter and parts • Plastic Sheets • Corner Brace • Hinge • Catch	 • 4 • 2 • 1 • 1	$86.95 • $68.05 • $6.58 • $1.29 • $1.29
Miscellanies • Cables and tubing • Shelf		$60.85 • $29.49 • $31.36
Total Cost		$555.34

Table 5.2: Final Cost of Solar & Rain Power Generator

As seen from the above table, we have got rid of the piezoelectric material because of its low efficiency and the poor productivity. In order to reduce the cost, we decided to manually build the turbine fan instead of buying one from the supplier. Hence, we only spent 20 dollars on the turbine fan which is a key component of our project. However, we underestimate the cost for the rain collector and miscellanies. This is due to the fact that there are many parts needed for the rain collector. In addition, we need a rack to support the water tank which costs us extra 32 dollars. The most significant discrepancy is the turbine fan shelter which prevents the water splashing. We necessarily need this to protect the turbine fan as well as to filter the water to ground. It was hard to find a suitable size of box to fit the turbine, therefore, we have to purchase the material and assembly parts to make it on our own. This costs us 87 dollars.

The biggest difference between the initial budget and the final cost is we did not have to purchase the piezoelectric due to its low efficiency. Also we got rid of the water filter system due to the limited time and we considered it as a future improvement.

6 Interpersonal Technical Experiences

6.1 Frank Feng - Chief Executive Officer

Over the course of the semester, I have worked hard with my team members and acquired a variety of new knowledge. As the CEO of the team, I was in charge of the team communication and decision making and, most importantly, monitor the quality of the design. I was involved with every single step of the project and kept all the team members being active. In terms of my contribution, I was responsible for the electrical system design and helped with the user interface implementation. I have gained valuable knowledge of different voltage regulators and their corresponding protection circuits. I constructed the circuit that delivers the maximum power to the load. In addition, I helped a bit with the turbine design and have done a lot of hardware cuttings and assembly works.

From the last past four months working on the Solar & Rain Power Generator, I have learned a lot of rewarding mechanical experience. I have used many tools that I haven't used before, such as jigsaw and laser cut. However, I have learned some general lessons. The most challenging task is not the technical work, but the team dynamics. It's really hard to have everyone fit the meeting time. We sometimes spent more time on waiting rather than solve problems. However, the results were satisfying, but we could make it more efficient.

Lastly, I really enjoyed working for the Team GPI for the past 4 months. It's not only the completion of the project, but also the dealt with great frustrations and troubles that kept us looking for the solutions.

6.2 Zhiyu Hu - Chief Technical Officer

ENSC 440/305 is by far one of the most challenge courses I have encountered in my undergraduate degree. The course not only significantly improved my team & time management skills bout also made a great level up on my technical skills especially in mechanical engineering.

As the Chief Technical Officer, design and implantation of water turbine system for GPI Solar & Rain Power Generator is my major responsibility. Moreover coordinate with Jeff, Frank & Max and provide technical support when any of them encountered with difficulty is also a continuously task for me.

The design and implantation of water turbine system are full of charlages from start till end. Although the basic concept of hydropower is not new to us, to design suitable and makeable water turbine is rather a complex process. Unfortunately, there is very little knowledge we have learned through the past 4 years as most of us is majored in electronic engineering. After about month of researching and learning, we finally come up with a suitable design. However, to produce the real mode is more difficult than just design. There are no similar water turbines in market, moreover, we are limited buy time and budget to buy a custom made water turbine from plastic molding company. 3D print is an also failed approach because of the limited materials strength and relatively small demotions limitations. The solution is rather dramatic; we build the water turbine with 12 spoons. The idea just came out when we dinner together, the size and shape of that dining spoon is perfect as a single blade on our turbine. Throughout the integration of the turbine system I have greatly improved my hand craft skills and learned principle theory of turbine design (Affinity Laws, Runaway speed test) and familiar with many different types of water turbines.

In terms of the team dynamics, I think we have worked pretty well beside delay for the milestone time line. The delay is due to the change of system overall design, after we get feedback from Andrw and we notice major disadvantage of our design, as a result physical layout of the system has been modified. So all of our previous work had be reversed, which result to an unexpected delay for project process. Thanks to my team, especially Jeff and Frank, without their help, the water turbine could never be fished.

If we could carry on the development of the GPI Solar & Rain Power Generator, I would like to work with the same team without any hesitation.

6.3 Jeff Bian - Chief Operating Officer

In the past four months, I worked with four intelligent engineers', Frank, Zhiyu Hu, Max, and Xiao Dong. I gained the knowledge of mechanical design and hardware technology by creating our solar and rain power generation system. I also improved the experiences of documentation, creative thinking, and team working management.

As a COO of Green Power Innovation, my main role is to design and build the user interface. I decided all the user interface functions and made several changes during the design progress. Initially, I decided to use a microcontroller to program the whole user interface. However, the budget and limited time do not allow our company to implement this design. Hence, I design the user interface by using hardware. After finish the entire design, Zhiyu Hu and Frank helped me to build and test the user interface. I also focus on daily operation of the entire project and prove technical support for other hardware building (e.g. turbo fan, turbo cover, and LED application)

The most difficult part for our project was seeking the suitable turbo fan to fit our DC power generator. Zhiyu Hu (CTO) and I designed several turbo fans. We also selected different size of components and chose different materials to build our turbo fan. Although it was a difficult challenge, we finally built a suitable turbo fan to achieve the highest efficiency to generate electric power.

After taking ENSC 440, I am glad that I finished our project and achieved our project purpose. I will also appreciate my group members and Dr. Behraad. They gave me lots of inspirations and technical supports. I am so glad that our project was successful.

6.4 Xiao Dong - Chief Financial Officer

During the four month working with members in GPI, I gained a lot of experiences, it was very interesting and fun to working on members for our project. It is very glad to see that a after 4 month of hard working we are able to build a system that we could be proud of. This project and working experience is an unforgettable experience for me.

As a chief financial officer, I am response for choosing the materials and control the budgets. As well as assistants for integration and testing. I gained a lot of experience with solar panels, power generators and plastic panels. Even though our project is working as we designed, it actually could be more efficiency. For example, we mistakenly choose a very high value power generator which could generator more than 100W power, but the water could make the generator runs at that speed, we could only generator around 10 to 20W power. As a result, some of the money was wasted on this item.
As a group, we were keep updating and journaling each other's ideas, and help each others to solve for problems. Working together as a team on a project is a unique and valuable experience. From not knowing each other’s strength and weakness to becoming best buddies really bonded our team as a whole. I feel proud to have such

a wonderful team and I wish that we will be able to work together again in the future.

6.5 Max Liu - Chief Marketing Officer

I feel I have learned so much during the past four months with four other great group members: Zhiyu, Frank, Jeff and Xiao. This project gives me the opportunity to use the knowledge learned in class on self-designed and self-made project.

As the chief marketing officer, my main duty is to design and build the water tank for water storage and release. I calculated the size required for each component and design the location of each component in order to have the water tank working properly. I also helped Zhiyu to make the mechanism for turbine and water-protection boxes. We then integrate it to the complete module of power output.

I also learn that it is super important to design carefully before actually starting to build, otherwise it will take much more time overall because imperfect design takes additional time to fix and redesign. It is also better to start early than start late because people always get busier as semester goes, which also means that we need to schedule better with taking the consideration of exam conflict. One more thing I learned is when I am working on my project, I need to be very careful on making every step because a tiny mistake could lead to a rebuild of the module. I also learned that team work is very important as they are some tasks that I need to work with my other group members in order to complete them. The last thing I learned is that to forgive mistakes caused by other group members because mistakes are not something uncommon and everyone will make more or less mistakes.

I would like to take this opportunity to thank all my other group members and all the faculties that helped us. This project was a great challenge for us but we overcome all the problems and we are able to finish the project by the end.

7 Reference

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