Fall Final Report

Team 9
Power Converting Sub-System of Kite Power Generator

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Table of Contents

Table of Figures

Table of Tables

ABSTRACT

There is an ever-growing need for clean, alternative energy sources. The purpose of this project is to design, build, and deploy a kite power generator that will power a 40W lightbulb. This design will then be scaled to generate 100kW's of power. The scaled kite will be a conceptual design. In addition to generating 100kW of power, the conceptual scaled kite will also have a system that will draw moisture in from the surrounding atmosphere and deliver that moisture to the ground. To generate power, the kite will be tethered to a permanent magnet within a housing that contains an electric coil. As the kite is subjected to a wind load, the kite will pull the magnet through the coil. When the load decreases, a system of springs will force the magnet back through the coil housing. Electricity is generated each time the magnet slides through the electric coil. In order to achieve a constant oscillation of the magnet, the kite will be flown in a figure-8 pattern.

ACKNOWLEDGMENTS

Thank you to Jeff Phipps for making himself available through email to answer our questions in regards to this paper and for coming up with the original idea for this project. We would also like to thank Dr. Shih and Dr. Gupta for presenting us with this project and giving the opportunity to execute the desired tasks.

1. Problem Statement

The worlds energy consumption is expected to rise by 48% by the year 2040[1]. Oil, one of the most commonly used forms of energy, is a limited resource. For this reason, there has been an increase in demand for new, alternative forms of energy. Some of these alternative forms of energy come in the form of wind turbines, solar panels, and nuclear energy, each of which have their own advantages and disadvantages.

Wind turbines are commonly used along the Midwest of the united states. They are large, stationary, and loud. Many people consider them to be an eye sore who see them every day. They also require a large amount of maintenance due to wear on the gearboxes that are used to maximize power output. Solar energy can only be used to generate power when there is sunlight that can be absorbed. This means that they are limited in time and season, when they can be useful. Nuclear energy has an inherent risk of contaminating the area around it if something were to go wrong with the facility. This has been the cause to numerous city wide evacuations all over the world.

In addition to a need for new alternative forms of energy, there is also a need for fresh water in some regions. One of these regions is the Greek island. Focusing on this region not only provides us with data of an annual wind speed to optimize for, but also creates a need for a water collecting system that will be attractive to the market.

For these reasons a kite power generator will be created. This device will also have a conceptual water collecting system so that we can have an edge up on other forms of power generation that are also new to the market. Figure 1 Jeff Phipps patent that has been the base design for the design.

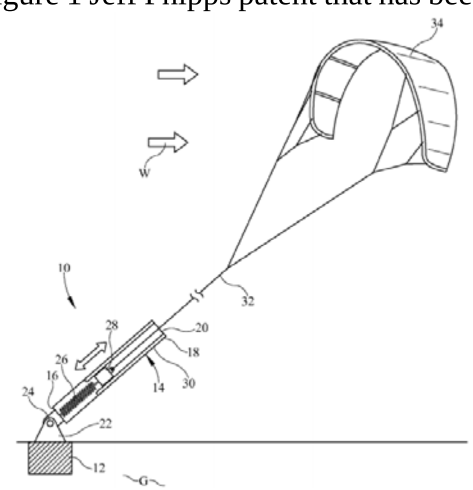


Figure 1. Jeff Phipps Pogo Solenoid Patent [2]

2. Project Scope/Goals

The scope of this project is to create a kite powered generator that will generate enough power to light up a 40W lightbulb. Knowing that the kite will not be able to maintain a constant supply of power, the system may be used to charge batteries that will then be used to power the lightbulb. This decision will be based on the success that we have when running tests using the demonstration model. The kite that is attached to the demonstration model will need to be controlled and flown in a figure-8 pattern to increase the efficiency of the oscillations. Some automatic, or mechanical input will be the driving force that will fly the kite in this pattern.

In addition to a demonstration model, a scaled kite will be conceptually designed that will generate 100kW of electricity. This kite will include a system that will also collect water and deliver that moisture to the ground. This is being added to the official scope of the project because of a recent discovery of new product to the kite power generating world. Makani kite power is able to generate 600kW of power which is far beyond our current expectations, and does it in a more controllable fashion. Therefore, a main selling point for this kite is the water collecting feature that would make it ideal for regions such as the Greek Islands. We will perform a failure modes analysis on this conceptual kite, so that future teams are able to see what design considerations they should take more seriously.

The main goals for this project are as follows:
1. Demonstrate that a magnet inside of an electric coil that is oscillated using a kite will generate usable electricity.
2. Come up with an idea that will allow for maximum energy output based on varying wind speeds.
3. Show commercial potential for this product so that it can be taken to the market.

To meet the goals of the project, working together and scheduling out tasks ahead of time plays an important part and ensures that things get done. Every team member is assigned with a position and tasks to complete based on their strengths in the field in order to complete the project as efficiently as possible.

3. Project Objectives

One of the goals of the project is to demonstrate that a magnet running through an electrical coil can generate usable electricity. This goal can be completed by attaching a lightbulb to the system so that it generates enough electricity to power 120 volts. The kite will be tethered to the magnet inside the coil where the varying tension on the tether will make the magnet oscillate and generate a voltage. Part of this design will be controlling the kite to fly in a figure-8 pattern as well as figuring out a way to increase efficiency of the system during variable wind speeds. Once this design is built, the team will test the model to demonstrate the power generation portion and complete this goal.

In addition to supplying 120V (enough to power a 40W lightbulb), there will be a plan for a concept kite that will produce 100kW of electricity. This will be done at the end of the project once the demonstration model is complete in order to show how the device can generate maximum power. The team will perform the necessary calculations to allow the system to generate 100kW. The final goal of this project goes hand-in-hand with the energy optimization. The team must show commercial potential by showing how this system can generate maximum power. Additionally, since this is optimized to be used in the Greek islands where there is a water shortage, a concept generation for a water collection feature on the kite will need to be made. In the current market, Makani is a company that is excelling in producing maximum power from a kite, roughly 600kW, thus the competition has gotten high in the kite power industry. This water collection feature in this project is something that sets it apart from any other company in the market.

4. Plan/Methodology/Approach

Through weekly meetings with the sponsor and advisor, the customer requirements and scope of the project has constantly evolved. There are also bi-weekly meeting with the team in order to solve problems that emerge, catch up on each team members individual tasks, and perform assignments that are required to be done as a team. The tasks being carried out to start the spring semester include ordering parts for the grounding plate, housing, and kites which will be carried out by Denitsa Kurteva. Matt Hedine will focus on finalizing the designs for the grounding plate and the housing. Zachary Ezzo will focus on deciding what materials will be best used for grounding plate and housing as well as the type of kites that are ordered. Andrew Colangelo will be tasked with locating a machine shop in order to build the housing and ground plate as well as locate a 3D printing shop that can create the spool for the solenoid to be wrapped around. He will also communicate with our sponsor, advisor, and team in order to set up necessary meetings. After these tasks are completed, the demonstration model testing can begin and refining can be done.

When it comes to making modifications to the demonstration model it will be a group effort, and an iterative process. We will all need to learn how to fly a kite and once that is achieved we can start to work on ways to make the kite fly in a figure-8 path automatically. The water collecting feature also will to be a group brainstorm. We will likely need to have half the group focus on refining the demonstration model and half the group focus on the concept model once we have a working device.

5. Progress Made

Throughout our fall semester, our team was able to make a good amount of progress on our project. The key milestone that we were able to achieve was finalizing our demonstration model. Throughout the many discussions that we had with our sponsor, our design for the kite power generator changed routinely. After making progress in one aspect, we would converse with our sponsor and the idea would steer in a different direction. Therefore after our lengthy meetings on the conceptual side of the project, we were able to finalize a model that pleases everyone.

One of the main focuses of our demonstration model is a spring stiffness variation. Our team decided not to add too much complexity to our model by using a motorized machine to alter the spring stiffness. We wanted to put our focus on the power output with as little power input as we could. Through research and testing, we decided on the approach of using concentric compression springs for the spring stiffness variation. These springs work with a step response manner and require no power input.

We also took steps forward in our kite design over the last semester. After research and comparisons, we were able to finalize a kite stabilization method. For our project, the most efficient way for our team to stabilize the kite while in flight is to utilize kite tails. These tails are light and have been proven to work on any type of kite. They provide weight and drag to the kite from the rear, which will keep the kite facing the direction of the wind at all times. We also decided on our approach to altering the angle of attack. We are planning to use a winch to control the two strings of the kite to be able to manipulate the kite to our desired path. Ideally we want the kite to fly in a figure-8 pattern to generate the most oscillation. To be able to manipulate the kite to fly this way requires power input, therefore we felt that a winch would be the most practical way. We are still in discussion within the team and with our sponsor about where exactly the winch should be located to be the most efficient.

Also we have determined the optimal conditions for our model to generate the necessary power needed to light a lightbulb. There are many factors that contribute to the power generated, therefore we had flexibility when choosing our materials for our demonstration model. We decided to go with a 1.32 Tesla magnet which creates a strong magnetic field thus not requiring us to create a large scale demonstration model. The parameters that we are working with allow a user to easily control the demonstration model while producing the required power needed.

At the beginning of our return this semester, our team currently has the parts that were ordered over break and are now in the process of building the demonstration model. We plan to outsource the construction of the housing but will assemble everything together once the housing is completed. Figure 2 shows the model that will be used to demonstrate the wing power generation.

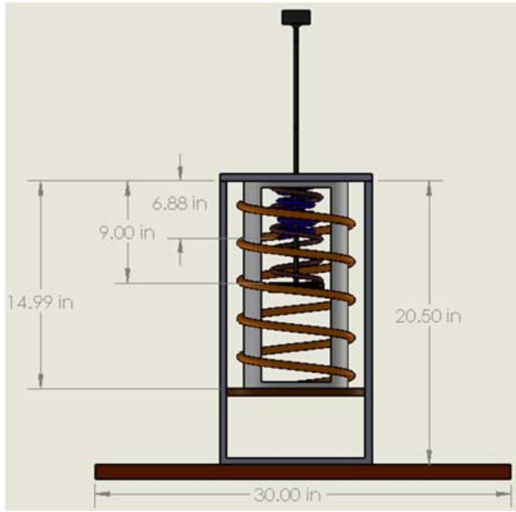


Figure 2. Demonstration Model using three concentric springs

6. Challenges/Constraints

When designing the power generating subsystem of a kite power generator it is important to know what limitations there are for a specific design. For the project that will be executed the power generation will be optimized for altitudes between 500 and 1500 feet. The kite generator will also be optimized for a specific region, the Islands of Greece. The altitude constraint along with the geographic constraint will allow for the design of a kite that a certain nominal wind speed for that region and altitude. The kite must also deliver AC power to the grid so that it is generating usable electricity. The parts that are used in the assembly of the kite power generator must be off the shelf-products to allow for efficient assembly of the system with no manufacturing of custom parts involved. It is important to operate within these constraints to ensure that the concept designs are on target and will achieve the desired function.

During the process of designing the kite power generator, there are some challenges that are foreseen to occur. The demonstration model that will be built will have a kite that needs to fly in the correct pattern in order to generate the amount of electricity that is predicted. This creates the challenge of controlling the kite whether it be manual or automated. If the control is manual, then the person tasked with controlling the kite will have to gain enough experience in order to do so correctly. If the control is automated, complex coding and motors will need to be added to the system which creates the possibility for more complications. The challenge of how to mount the grounding plate still exists as well. The housing assembly will be screwed into the grounding plate but it has still yet to be determined how the grounding plate will be anchored. This ties directly into the portability of the system. If the grounding plate is easily anchored and removed, that increases the overall portability of the system.

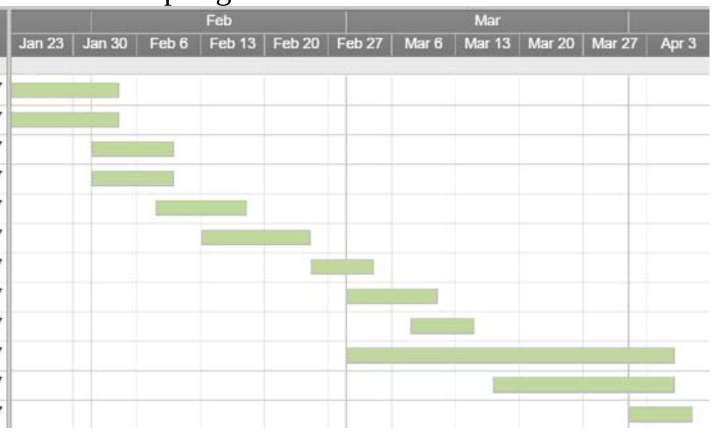
Another challenge that has recently resurfaced is the water collection feature of the kite. The feature was added back into the scope of the project to add commercial appeal and to help compete with other companies who have similar products. The water collection feature brings up the challenges of added weight on the kite and figuring out how to avoid water freezing on the kite in cold climates. The last challenge that can be foreseen is the feasibility of the scaled concept model. It raises the questions of how much bigger the system need to be in order to generate 100kW of power and at that size whether or not it will be efficient enough to compete with other forms of electricity generation.

7. Deliverables & Schedule

Figure 3 shows the schedule for the project presented in the form of a Gantt chart where it clearly shows the name of each task, the duration of the completion, and the beginning and end date, excluding ME deliverables since they are fixed assignments that will be competed alongside the project.

Table 1. Schedule for the spring semester

Task Name	Duration	Start	Finish
Order kites	10d	01/23/17	02/03/17
Finalize ground plate and housing designs	10d	01/23/17	02/03/17
Machine grounding plate	7d	02/01/17	02/09/17
3D print springs housing	7d	02/01/17	02/09/17
Test kites	8d	02/08/17	02/17/17
Kite control concept generation	10d	02/13/17	02/24/17
Kite control concept selection	6d	02/25/17	03/03/17
Kite performance optimization	8d	03/01/17	03/10/17
Concept kite material selection	5d	03/08/17	03/14/17
Demonstration model testing	26d	03/01/17	04/05/17
Refine demonstration model	14d	03/17/17	04/05/17
Finalize 100kw scale model concept	6d	04/01/17	04/07/17



In reference to the Gantt chart, the first task of the team this semester is to order kites that will be used to perfect the figure-8 pattern in order to generate maximum voltage from the generator. In the meantime, CAD drawings will be detailed and finalized of the grounding plate of the generator and the housing for the springs. A week later, these drawings will be machined in the shop or 3D printed. Shortly after, the kites will have arrived and the testing can begin once the power generation portion has been assembled using the newly machined parts. Then, the team will proceed to generate kite control concept techniques, kite material selection, and compute calculations for maximum kite performance.

Once the team has had experience solely flying the kite, the testing of the entire system can begin. Iteration will continue for as long as a month until the power generation portion fulfills the needs of the project, which is to power a 40W lightbulb. Throughout testing, the team will be refining the demonstration model and ordering new parts if need be to fix any issues that may arise during testing. Once the team meets the needs of the project and has finished testing, the concept for the 100kW scale model will be generated. In this final step, the team will perform the necessary calculations to allow the system to generate 100kW of power in order to show commercial potential. The final concept will allow for maximum power generation since that is a goal of the project. The team also meets every week with the sponsor and advisor to stay on track with the tasks needed to complete the project. The team actively meets every week to work on tasks together, distribute work evenly, and discuss project details to ensure the team stays on track with the Gantt chart.

8. Summary

The main goal for this project is to prove that usable and sufficient electricity can be generated using a kite to oscillate a magnet inside of an electric coil. To achieve this there have been many obstacles, such as coming up with an idea to control the kite, finding a way to optimize the kite based on varying wind speeds, and working equations to find a system that will be capable of producing the necessary voltage. Kite stability will be achieved using kite tails. These are tried and true methods for kite stabilization and are a cost-effective way of maintaining flight. The power generation at varying wind speeds will be achieved using concentric springs that will exert more force when higher wind speeds are present, and less force when lower wind speeds are present.

Some of the challenges moving forward include coming up with a method to control the kites flight path on the demonstration model, conceptualizing a water collection method, and refining the demonstration model in order to achieve the desired power output. The challenges with the demonstration model will take testing and iteration. The kite control method for the demonstration model will likely be the challenge that we face moving forward. With that said, there is a clear schedule and timeline that will be followed to complete the tasks required.

References

[1] "U.S. Energy Information Administration - EIA - Independent Statistics and Analysis." *EIA Projects 48% Increase in World Energy Consumption by 2040*. N.p., n.d. Web. 21 Oct. 2016.

[2] Phipps, Jeff. "Patft » Page 1 of 1." *Patft » Page 1 of 1*. Uspto, 20 Jan. 2014. Web. 30 Sept. 2016.