Team 9: Development of Power Generating Sub-System of Kite Power Generator

Andrew Colangelo, Zachary Ezzo, Matthew Hedine, Denitsa Kurteva

Advisor: Dr. Kunihiko Taira
Sponsor: Mr. Jeff Phipps

Presentation Overview

- Project Scope
- How it works
- Concept Design
- Kite Stabilization
- Spring Force Variation
- Demonstration Model
- Future Plans

The Problem at Hand

- Worlds energy consumption expected to increase by 48% by the year 2040[1]
  - Wind turbine
  - Solar energy
  - Nuclear energy
- Water shortage in Greek Islands[2]
  - Wind speeds of around 20mph

Design and build the power generating system of a kite power generator, and scale for a 100kW concept kite.

Project Goals

- Demonstrate that magnet in electrical coil will generate usable electricity
  - Power a lightbulb
  - Varying tension in line/spring
- Concept for a method for optimization of energy output based on wind speeds
  - Scale for a 100kW kite
- Show commercial potential
  - Efficiency comparison

Constraints

- Altitude between 500 and 1500 feet
- Must deliver AC power to grid
- Limited to off the shelf products
- Optimized for Greek Islands

Figure 1. Picture showing mountainous Greek islands

General Schematic

Kite flies in unsteady wind conditions

String and spring are tensioned → Magnet moves through coil

Hooke's Law $F = -k\Delta x$

Spring pulls back on magnet → Magnet moves back through coil

Faraday's Law

$$V = -N * \frac{\Delta(BA)}{\Delta t}$$

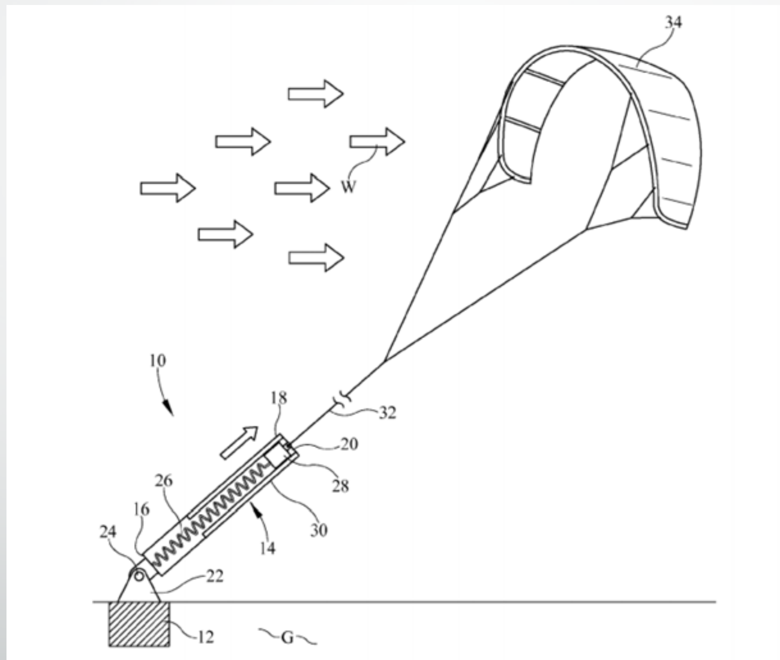
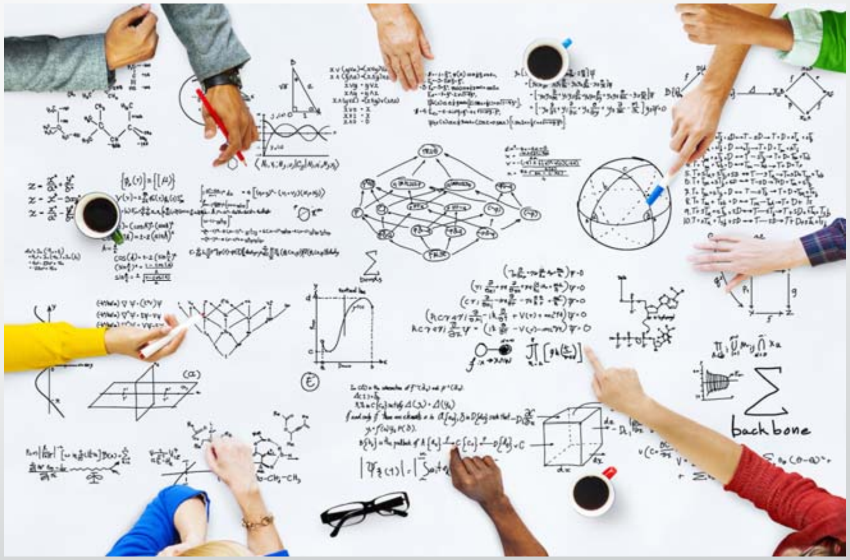


Figure 2. Jeff Phipps patent of power generating kite (diagram not to scale)[3]

Figure 3. Figure-8 kite path

Design Considerations

- Max power generation
- Kite control
- Mobility
- Ease of deployment
- Maintenance



Design 3: In-Air Winch

- Advantages
  - All tension goes into one string
  - Less surface area on ground
  - Less hardware
- Disadvantages
  - Winch higher in air
    - Maintenance issue
  - Less yaw control

Figure 4. In-Air Winch concept design (not to scale)

Kite Stabilization

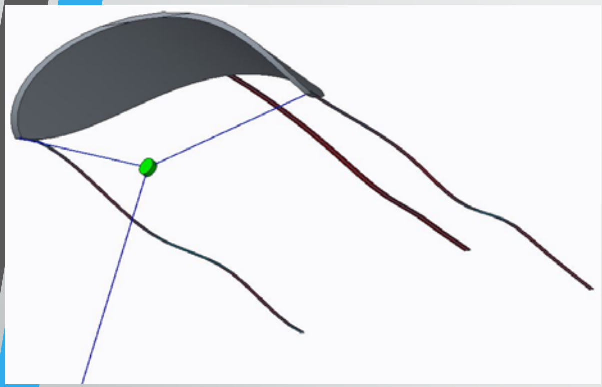


Figure 5. Kite Tails (not to scale)

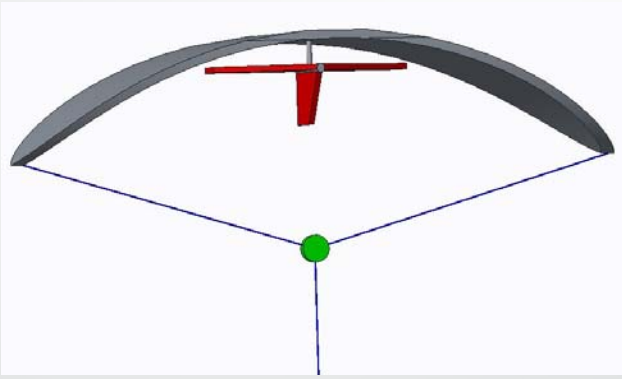


Figure 6. Kite with Rudder (not to scale)

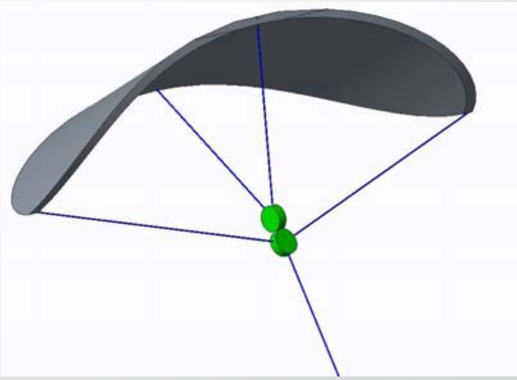


Figure 7. Double Winch (not to scale)

- Kite will need to fly in figure-8 like pattern to maximize oscillation

Spring Stiffness Variation

- Higher wind speeds correlates to greater tension
  - At high altitudes the path may not be followed
  - Safety mechanism
- Compression vs Tension Springs
  - Compression less susceptible to plastic deformation
- Different Methods
  - Motorized
  - Conical
  - Variable Rate
  - Concentric

Figure 8. Conical Spring

Figure 9. Variable Rate Spring

Motorized Spring Stiffness Variation

- Advantages:
  - Allows for greater variation of spring stiffness
  - Smooth transition to different stiffness
- Disadvantages:
  - Requires power input
  - Multiple parts could lead to failure
    - Spring may slip

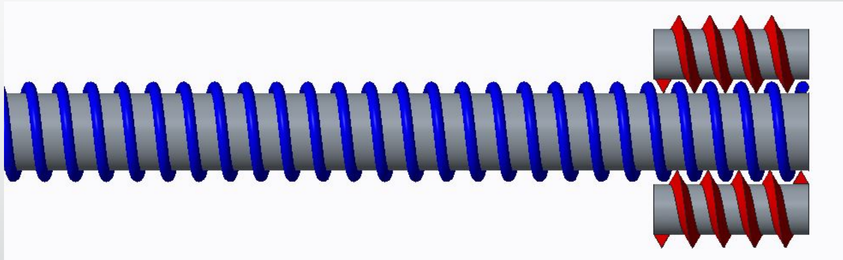


Figure 10. Motorized Spring Stiffness Variation

Concentric Springs

- Advantages:
  - No mechanical input needed
  - No added power
  - High safety factor
- Disadvantages:
  - Steps in stiffness coefficients

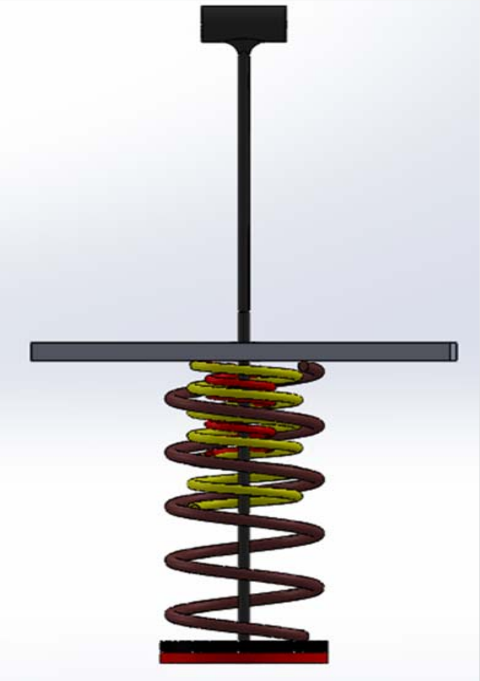


Figure 11. Concentric Springs

Pulley System

- Added Complexity to design
- May require customization of parts
- Can be used as a backup plan if desired speeds of the magnet are not achieved

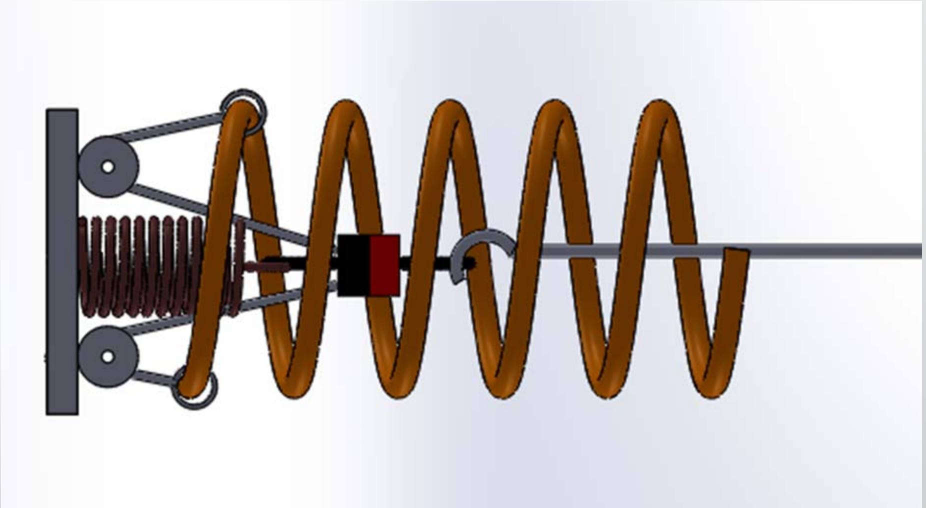


Figure 12. Pulley System

Detailed Demonstration

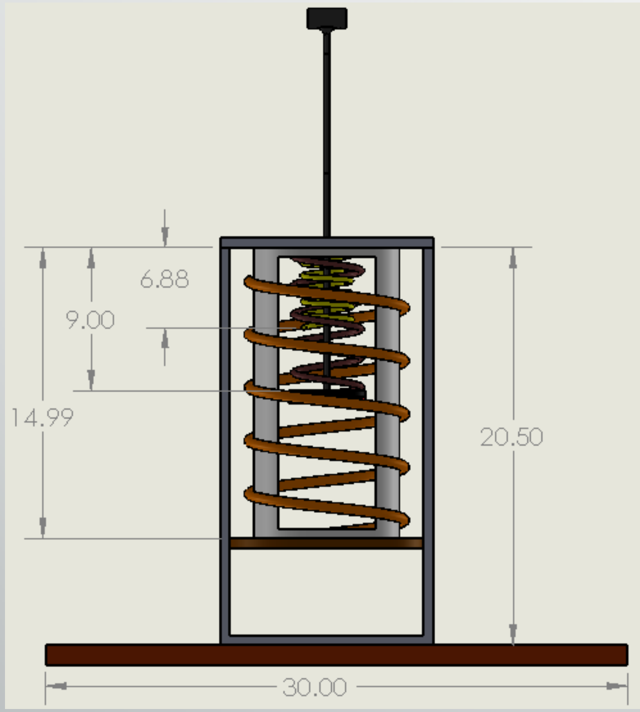


Figure 13. Dimensioned Demonstration Model

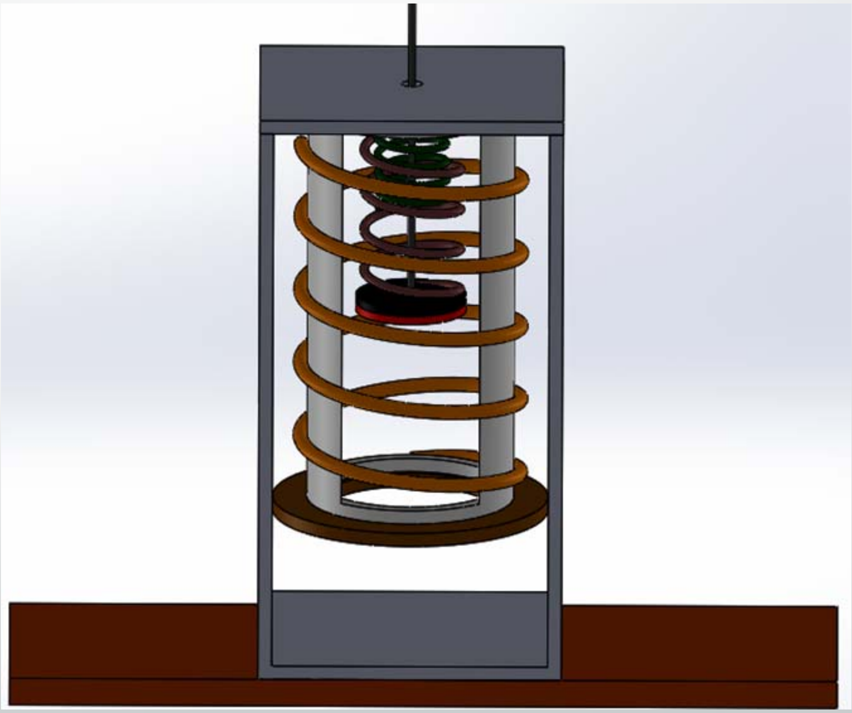


Figure 14. Demonstration Model

Parts Order

Table 1. Spring Selection

Spring No.	Length (in)	Stiffness (lbs/in)	Outer D (in)	Inner D (in)	Solid Height (in)
1	9	13	3	2.616	1.54
2	6.88	9	1.5	1.25	1.88
3	3.5	153	1	0.676	2.11

- **Neodymium Magnet 3 in x 1/2 in with 1/4 in Hole Disc**
- **13,200 Gauss = 1.32 Tesla**

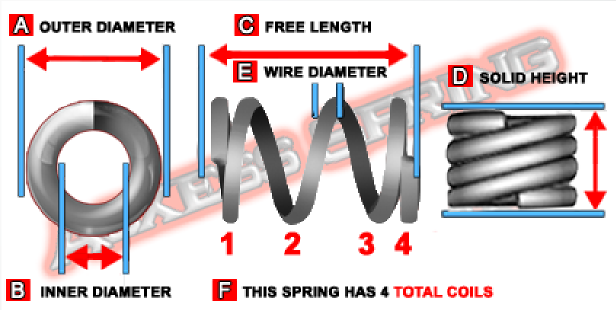


Figure 15. Spring Parameters

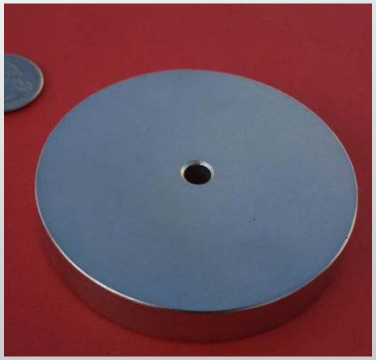


Figure 16. Neodymium Magnet

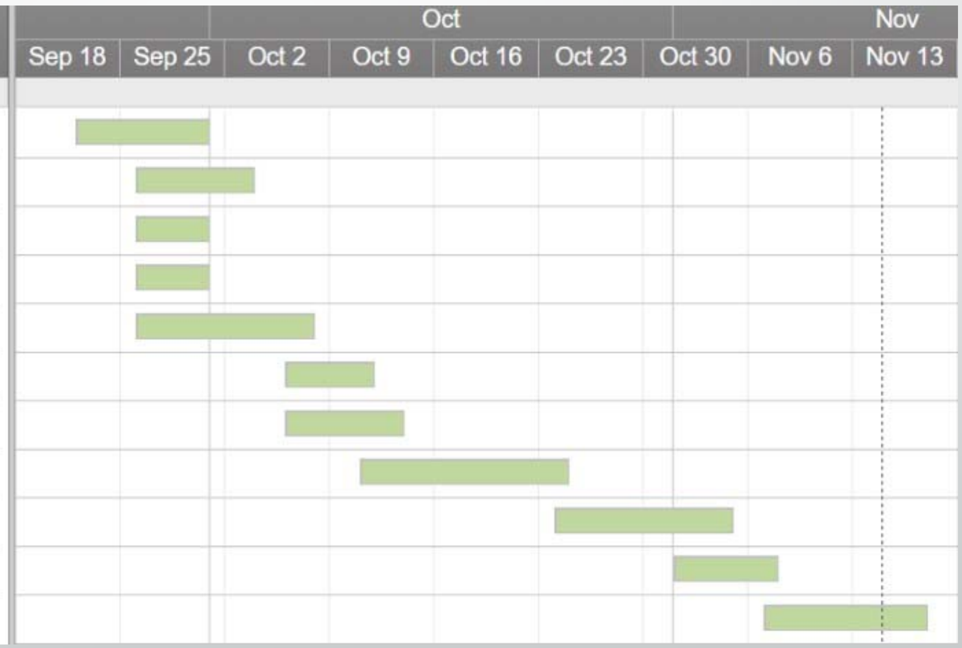
Challenges

- Method to retract the kite safely
- How to mount the grounding plate
- Feasibility for scaled model
    - What needs to happen for 100kW of power
- Portability

Gantt Chart

Table 1. Gantt Chart for semester

Task Name	Duration	Start	Finish
Meet group and advisor	7d	09/22/16	09/30/16
Contact sponsor	6d	09/26/16	10/03/16
Determine constraints	5d	09/26/16	09/30/16
Develop needs statement	5d	09/26/16	09/30/16
Conceptual design sketches	10d	09/26/16	10/07/16
CAD Drawings	4d	10/06/16	10/11/16
Concept Evaluation	6d	10/06/16	10/13/16
Optimization Concepts	10d	10/11/16	10/24/16
Concept Selection	10d	10/24/16	11/04/16
Material Selection	5d	11/01/16	11/07/16
Order parts	9d	11/07/16	11/17/16



Goals for Spring Semester

- Assemble demonstration model
- Begin testing
- Refining test model
- Finalize concept for 100 kW scale model
  - Failure Modes Effects and Analysis

References

[1] http://www.eia.gov/todayinenergy/detail.php?id=26212

[2] http://www.climatechangepost.com/greece/fresh-water-resources/

[3] https://www.uspto.gov/patents-application-process/search-patents

[4] http://www.conserve-energy-future.com/Disadvantages_SolarEnergy.php

[5] https://www.windfinder.com/weather-maps/forecast/greece#6/38.367/23.810

[6] http://www.kitenergy.net/technology-2/key-points/

[7] https://adrienjousset.wordpress.com/2009/09/15/kitano/

[8] https://www.ted.com/talks/saul_griffith_on_kites_as_the_future_of_renewable_energy?language=en

Questions?