# Team 9: Development of Kite Power Generator

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# Presentation Overview

- Project Scope/Goals
- Concept Generation
- Kite motion mimicking
- Demo Testing/Results
- Suggested Improvements
- Challenges
- Summary

# The Problem at Hand

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

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

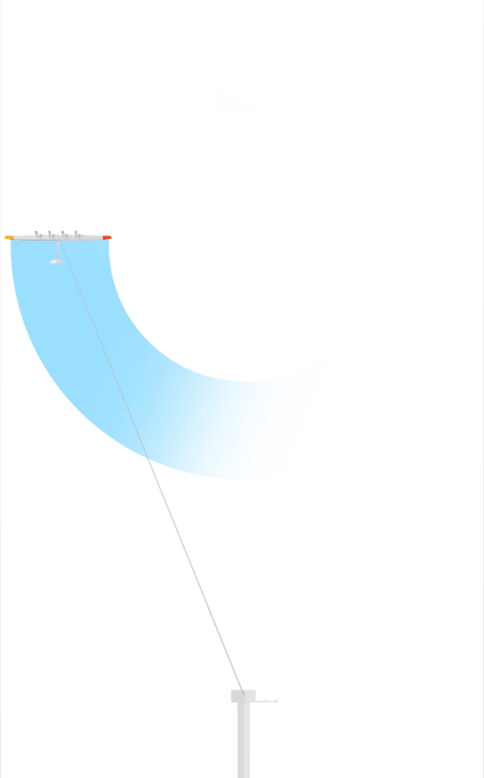
# Constraints

- 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

# Project Goals

- Demonstrate that magnet in electrical coil will generate usable electricity
  - Use a kite to oscillate magnet
  - Varying tension in line/spring
  - Power a lightbulb
- Concept for a method for optimization of energy output based on wind speeds
  - Scale for a 100kW kite
- Determine feasibility for mass power generation



Makani energy "kite"

# 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

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

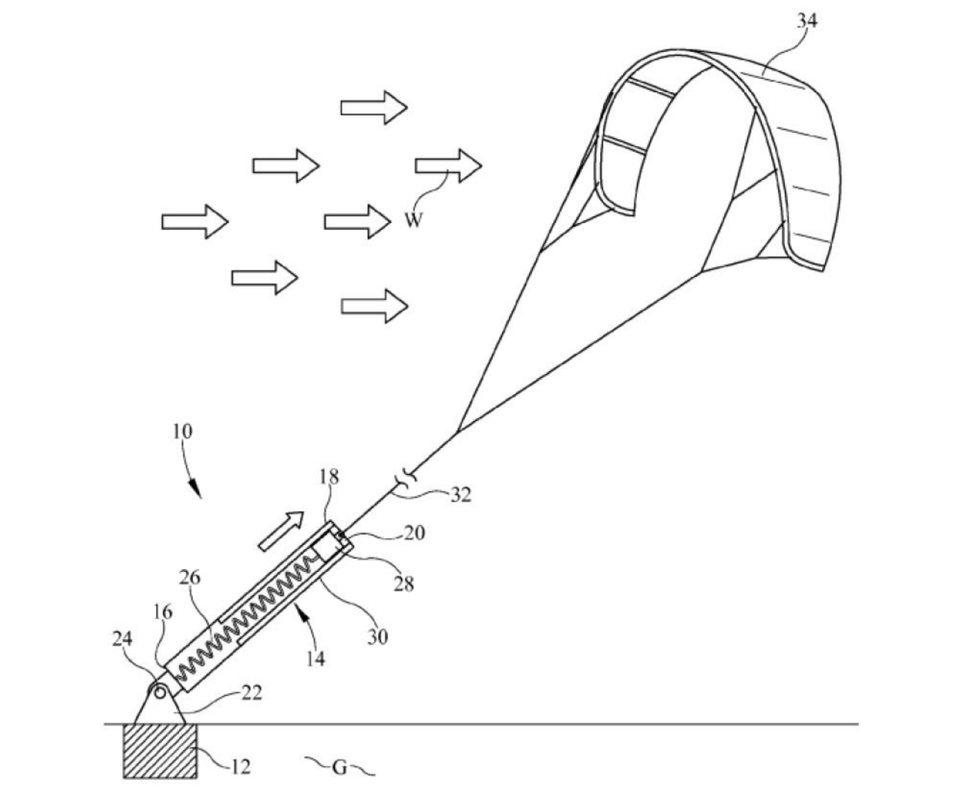



Figure 2. Jeff Phipps patent of power generating kite (diagram not to scale)[3]

Figure 3. Figure-8 kite path

# Concept Generation: Maintaining Oscillation

- Motorized Spring Stiffness Variation
  - Greater variation in spring stiffness
  - Requires power input
- Concentric Springs
  - No power input and high safety factor
  - Steps in spring stiffness
- Pulley system
  - Greater relative speeds between magnet and coil
  - Added complexity to the design

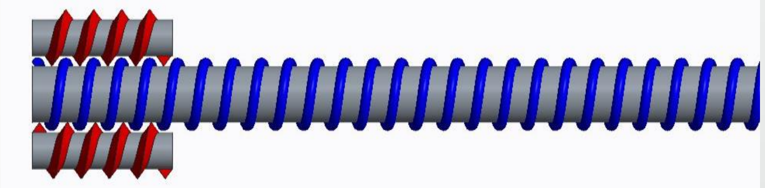


Figure 4. Motorized Spring Stiffness Variation

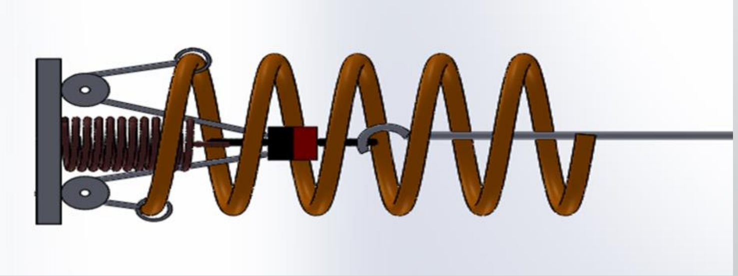


Figure 5. Pulley System



Matthew Hedine

# Concept Generation: Demo Model

- Concentric Springs were chosen
  - Simple design
  - Allows for variation in spring stiffness with little failure scenarios
- Determined optimal conditions for necessary power generation via Faraday's Law
  - Magnet speed/strength
  - Number of coils
- Magnet of 1.32T strength moving at a speed of 50 wraps/sec to power a 40W light bulb

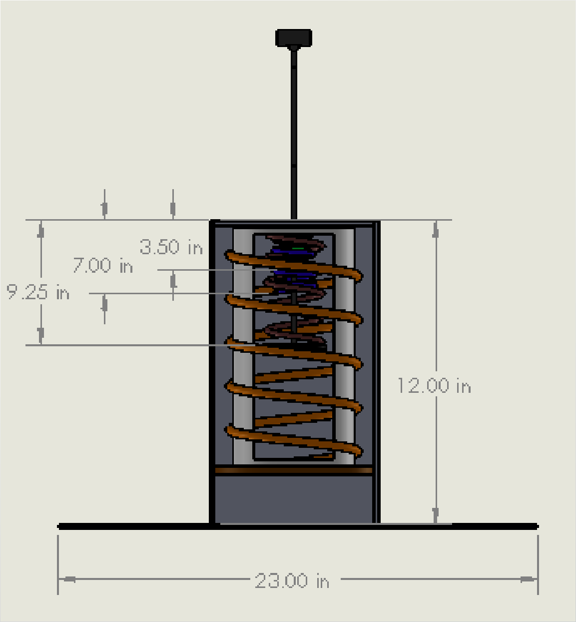



Figure 6. Concept for kite stabilization/control

# Concept Generation: Kite Selection

- Tested kites for maneuverability
- Traction and Stunt kite
  - Traction kite
    - More lift
    - Higher control
    - Slower movements
  - Stunt Kite
    - Less lift
    - Faster maneuvers
    - Less stable
  - Force output via spring scale
    - 3-5 lbs on straight path, 10-15 lbs on curves

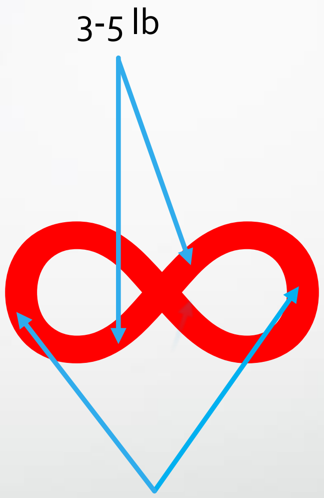



Figure 7. Measured forces along kite path


Figure 8. Traction kite that was tested

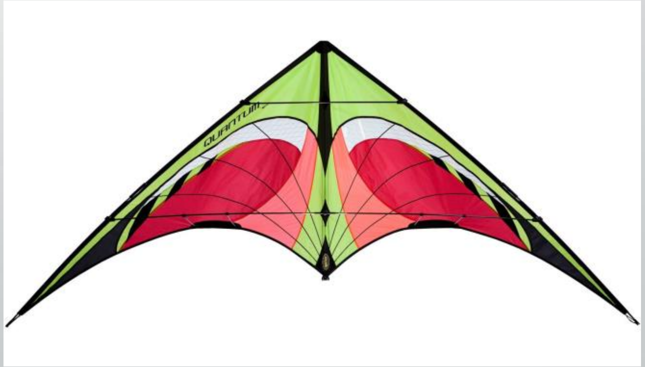


Figure 9. Stunt kite that was tested

Matthew Hedine

# Concept Generation: Lift Calculations/Kite Strings

- 35 mph headwind from 20mph wind at sea level
  - Lift force at 5 degrees angle of attack is 15lbf an 1.5lbf of drag
  - Lift force at 15 degrees angle of attack is 45lbf and 5lbf of drag
- 1/4″ Diameter Nylon String
  - Breaking Strength: 1805 lbf
  - Weight: 0.016 lb/ft
  - Mold and mildew resistant
  - Great strength to weight ratio
- String deflection was estimated to be ~0.5in
  - Negligible potential energy lost to string

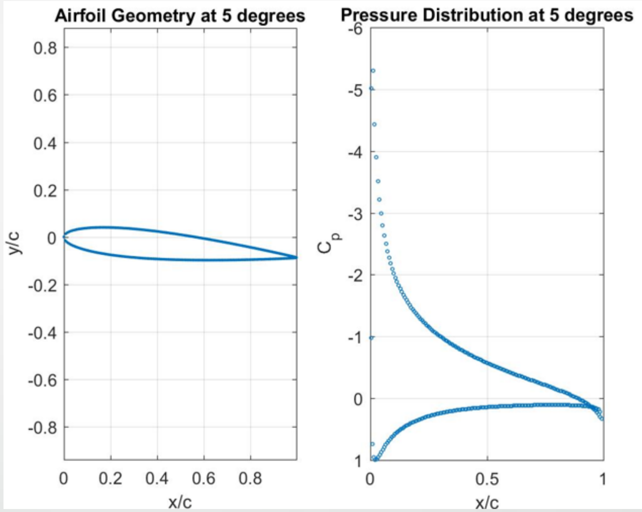



Figure 10. Pressure distribution at 5 degrees

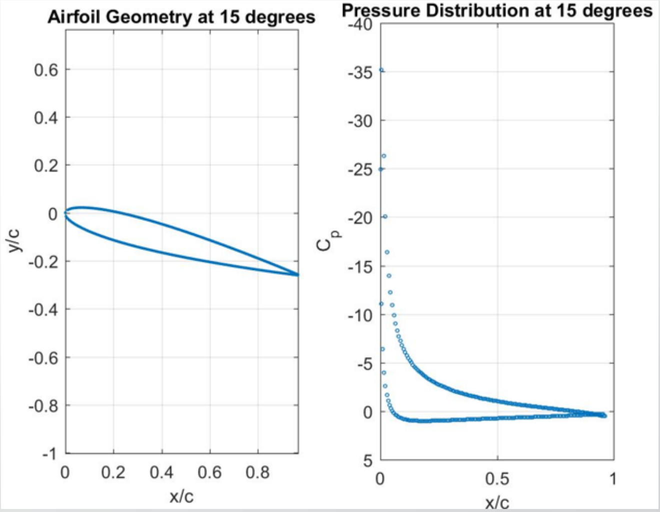



Figure 11. Pressure distribution at 15 degrees

# Mimicking Kite Motion

- Designed concepts for kite oscillation if kite cannot be correctly maneuvered
  - Motor will be used to mimic the tension in the line
- Allows for optimization of desired kite frequency
- Kite force can be varied by winding string around shaft
  - Compresses spring

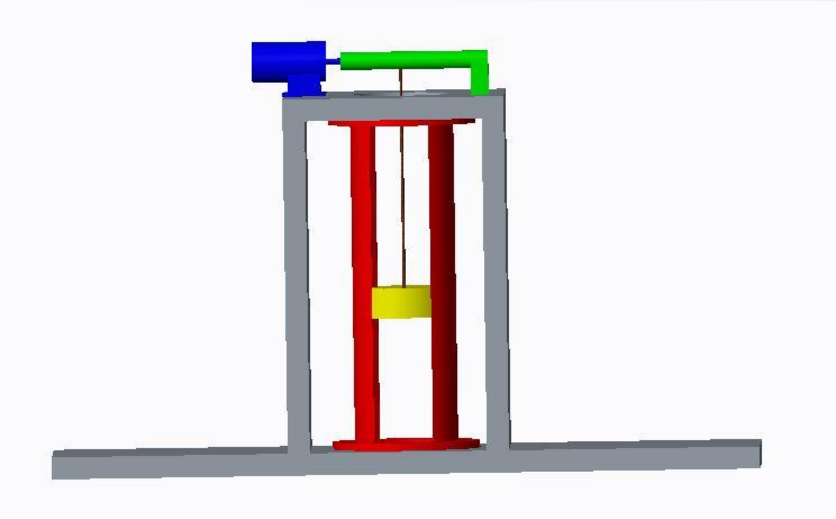


Figure 12. Motor to be used for kite motion mimicking

# Motor Selection

- High Torque motor
- Will be programmed to achieve different compression rates
- Different setups for different compression lengths

Table 1. Motor Specifications

| Motor Specs | |
|---|---|
| Continuous run torque | 21 in-oz |
| Startup Torque | 159 in-oz |
| Type | 12V DC |
| Shaft Diameter | 0.250" |
| Shaft Length | 1" |
| Max Speed | 3,000 RPM |

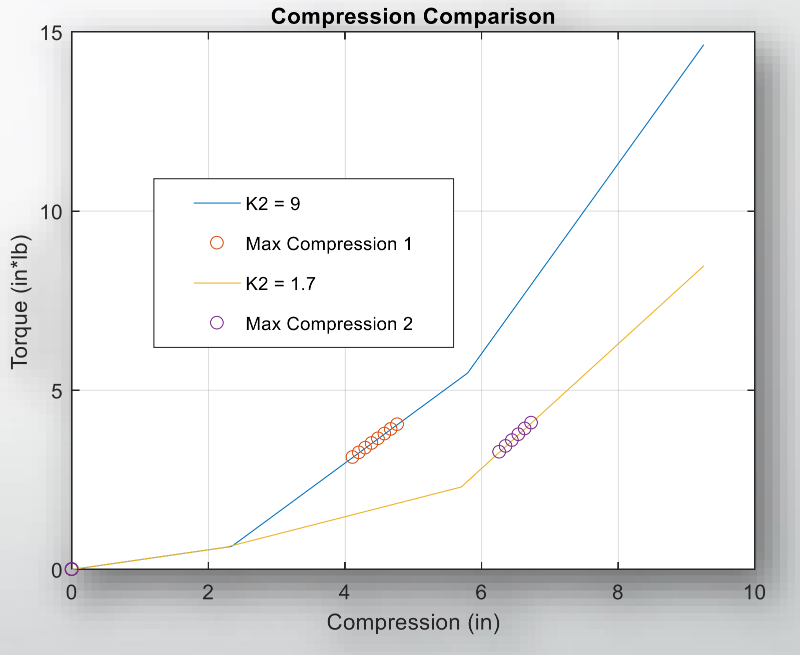



Figure 13. Compression of springs using selected motor

# Demo Testing: Kite Modifications

- Two lines tied from junction of all control stings
  - One on left, one on right
- Strings meet at quick clip in middle
- Single line down to power generator
- Voltage generation measurements from hand cranking
  - Max voltage was 0.5V
  - 2 orders of magnitude less than expected

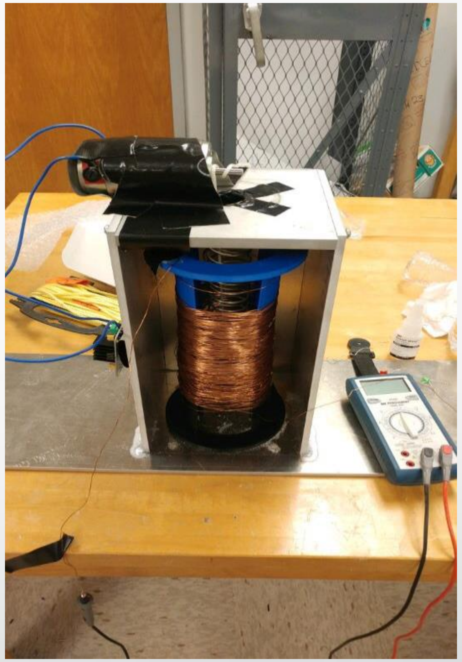


Figure 14. Demonstration model with motor attached

Figure 15. Diagram showing how 3rd string was attached

# Results from Demo Testing

- Kite folded when it reached max height
  - String to magnet snapped at higher altitudes
- Max Voltage reached was ~0.4V
- Not able to manipulate kite in a periodic manner
  - Third string was slacked at bottom of figure-8

# Suggested Improvements

- Multiple Magnets
- Lighter magnets
  - Smaller kite can be used to lift magnets
  - Faster  oscillation can be achieved
- Stiff winged kite
  - Framed power kite
- More wraps in coil with tighter spacing
  - Thinner wire = more wraps

Figure 16. Example of framed traction kite

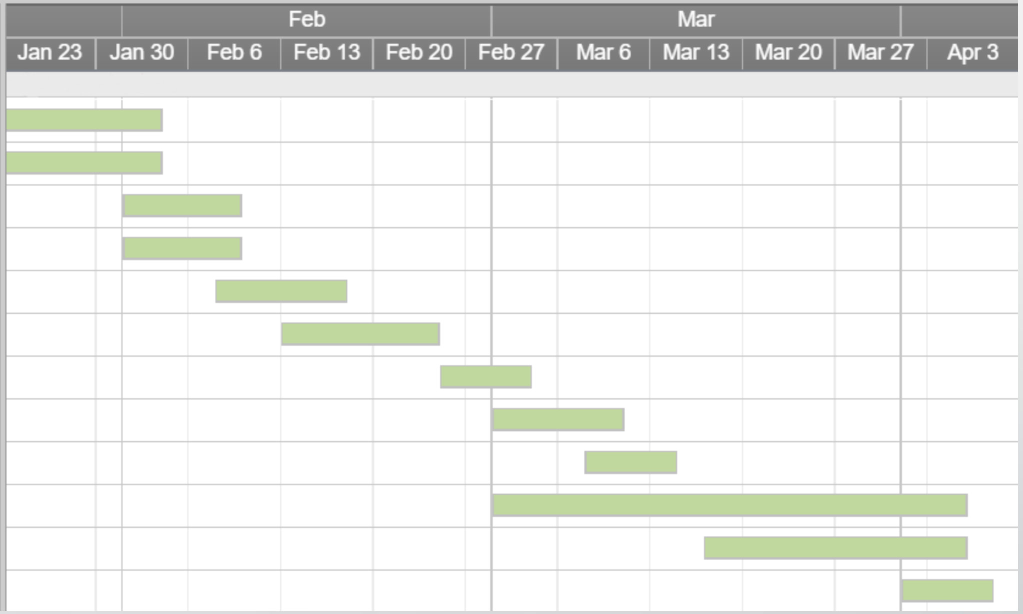
# Challenges Encountered

- Controlling demonstration model kite
  - Finding suitable wind to maintain steady flight path
- Attaching string to housing without loss in maneuverability
  - Length of third string
- Narrowing down the scope
- Much lower power generation than expected

# Planned Methodology

Table 2. Gantt Chart for 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 |




- Weekly meetings with sponsor/faculty advisor
- Bi-weekly meetings with team to tackle problems and catch up on individual tasks

# Budget

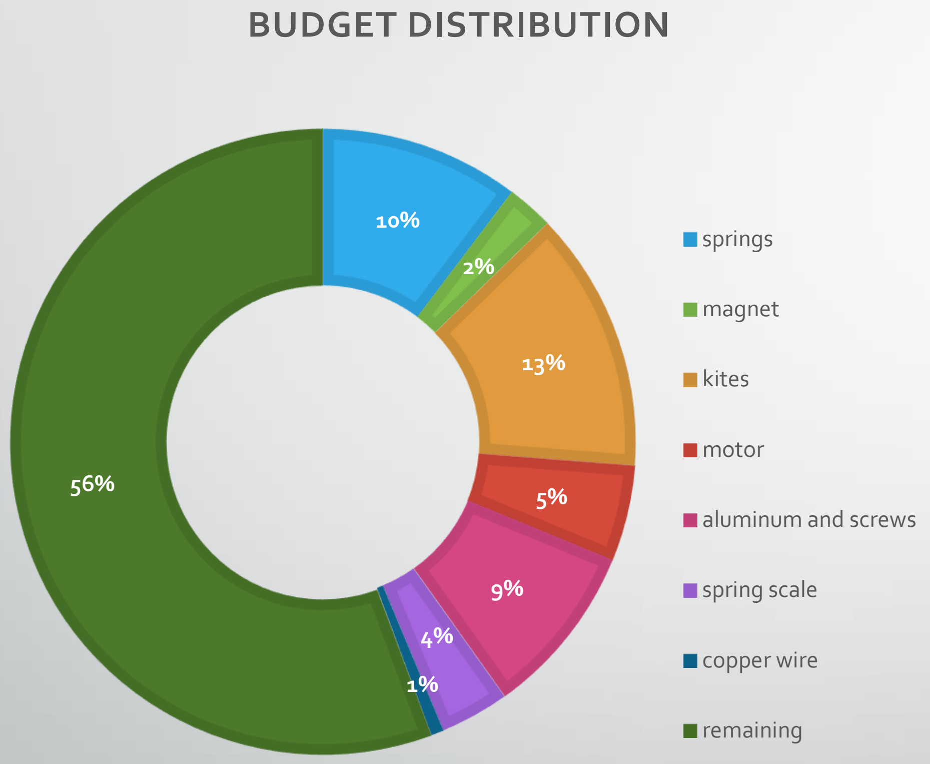



Table 3. Budget breakdown

| Items | Cost (USD) |
|---|---|
| 3 springs | 129.44 |
| Magnet | 48.26 |
| 2 kites | 270.27 |
| Al sheet | 162.93 |
| Copper wire | 13.2 |
| Spring scale | 71.13 |
| Screws | 16.00 |
| New springs | 76.69 |
| Acrylic rod* | 351 |
| DC motor | 99.53 |
| TOTAL | 1,238.45 |

Denitsa Kurteva

# Summary

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

- Demonstration Model has been assembled and preliminary test has been conducted
  - Concentric springs used to vary the spring coefficients based on wind speeds
  - Induced voltage 2 orders of magnitude lower than expected
- Motor is used to simulate kite motion
  - Allows for variation in the oscillation of the magnet
- There is commercial potential, however refinements need to be made
  - Add more copper windings, and magnets
  - Wild AC → Rectifier → Battery Storage → Usable Power

Denitsa Kurteva

Thank you!

# 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?