EML4552 – Team 15 – 02/16/16

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Portable Wind Turbine

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Overview

- Project Scope and Objectives
- Wind Turbine Base
  - Modeling
  - Analysis
- Base – Nacelle Connection
- Electrical Components
- Turbine Blades and Mounting
- Budget Overview
- Moving Forward
  - Prototype Testing

Project Scope and Objectives

- Objective: create lightweight, portable wind turbine that is easy to assemble and disassemble so that inexperienced operators may use the device.
- Revised Objectives/Constraints
  1. Operate in wind speeds of 4 m/s (~9 mph) at an approximate height of 2m
  2. Lightweight (80 lb max)
  3. Easy to assemble and disassemble
  4. Prototype (Budget of $2,000)
  5. Power output of 5W

Turbine Body - Design

- Design modeled in Creo Parametric
- FEA Analysis
- RISA 3D

Figure 1. Turbine Base Design

Turbine Body- Design Cont.

- Telescoping Legs
  - To accommodate for sloped surface
  - Clamps
    - Testing
- Plate connecting legs and neck
- All Terrain Feet
  - Screwed into bottom of legs

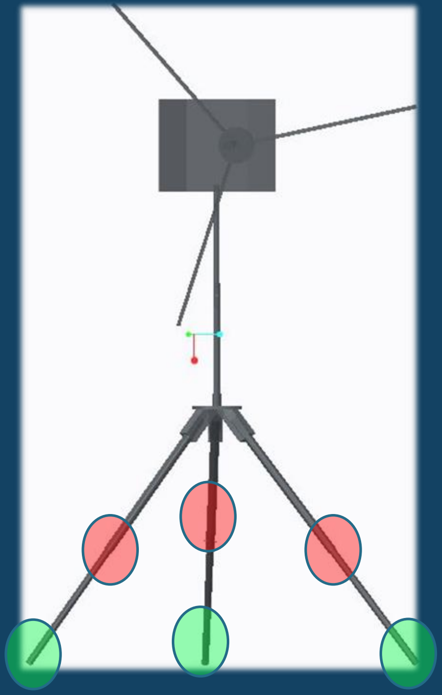


Figure 2. Part location

Figure 3. Tube Clamp

Figure 4. Base Feet

Turbine Body - Calculations

- Determined maximum angle of legs
  - 55.44 degrees
  - Chose 50 degrees
- Failure Calculations
  - Bending and Axial Stress
    - 11.93 ksi with a factor of safety of 2.93
  - Buckling
    - Negligible
  - Shear
    - Negligible

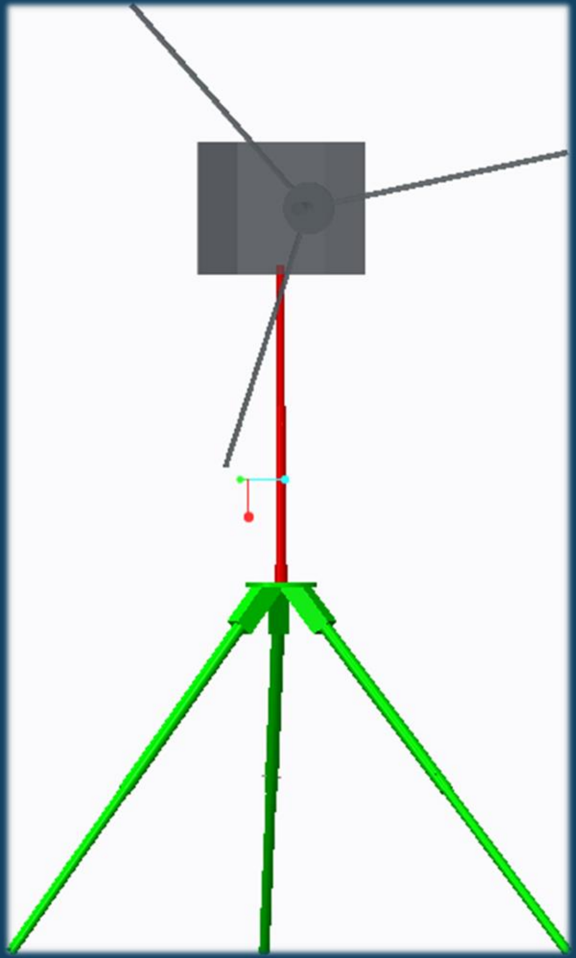


Figure 5. Turbine Base

Turbine Body - Calculations

- Overturning wind speed
  - 9.26 m/s (20.8 mph)
  - 6.55 m/s (14.7 mph)
- "Bump" Displacement
  - 15.5 inches at center of nacelle

Base – Nacelle Connection

- Must allow easy assembly/disassembly
  - Minimize/eliminate tools required
- Selected Steering Wheel Quick Release

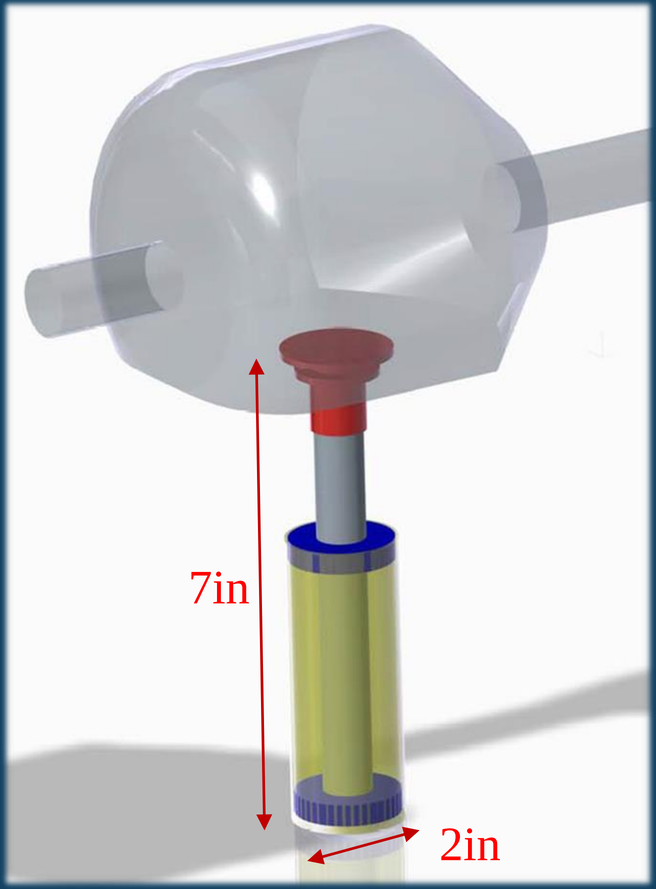


Figure 6. Joining of Nacelle and Base

Electrical Components

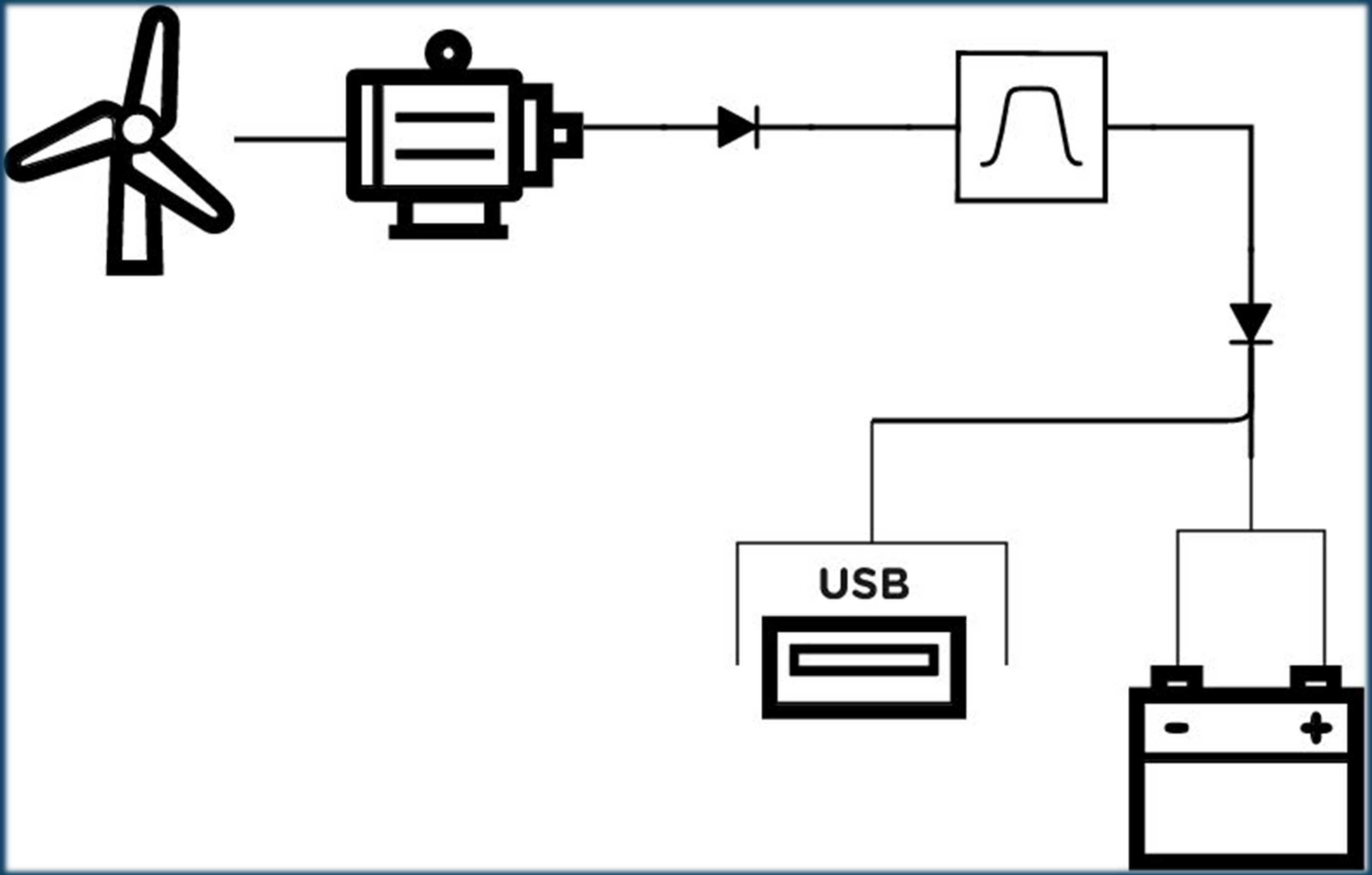


Figure 7. Electrical Schematic

Electrical Components - Generator

- Selected WindBlue Power DC-540
  - Permanent Magnet Alternator
  - Designed for low wind
  - Ordered - $239.00

Figure 8. Digital Tachometer

Figure 9. DC-540 PMA Generator

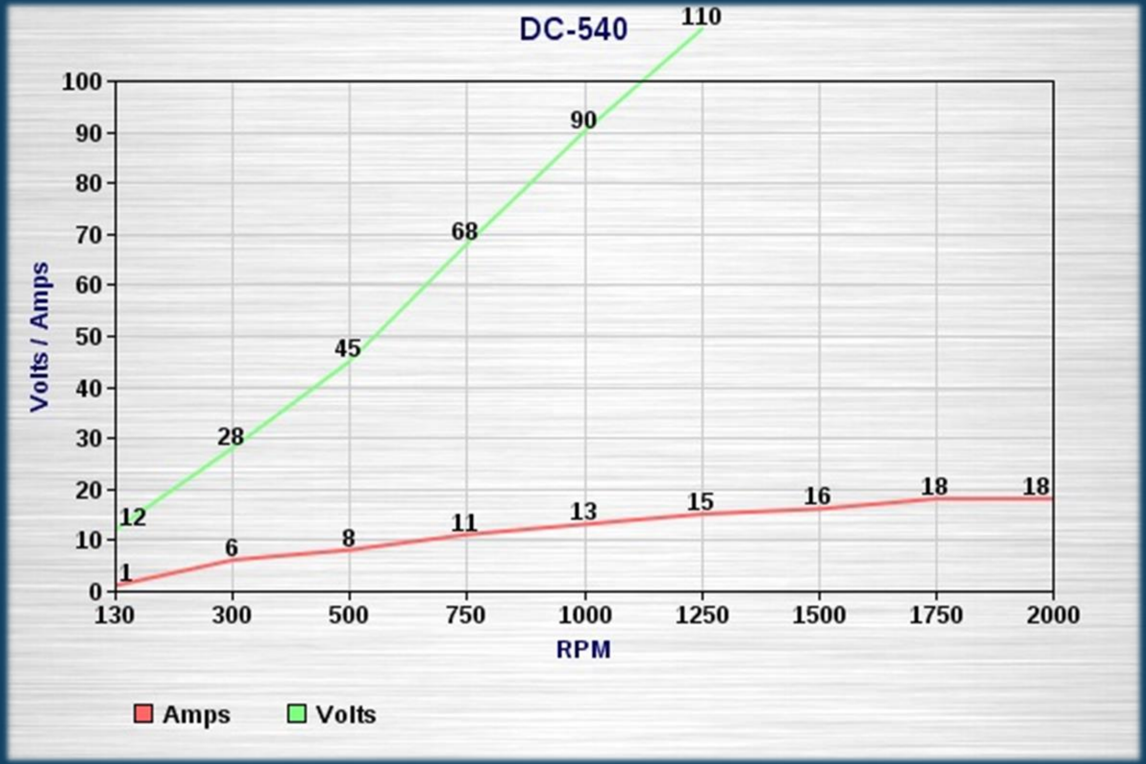


Figure 10. DC-540 PMA RPM vs Volts and Amps

Blade Connection

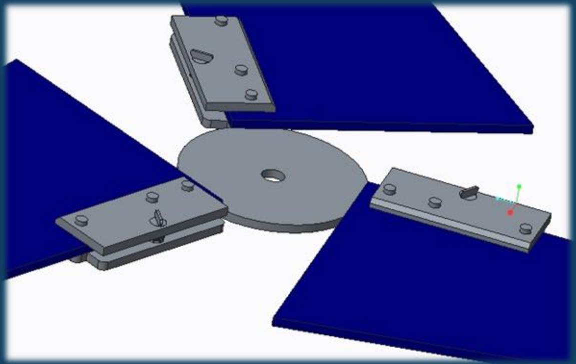


Figure 11. Pressure Clamps

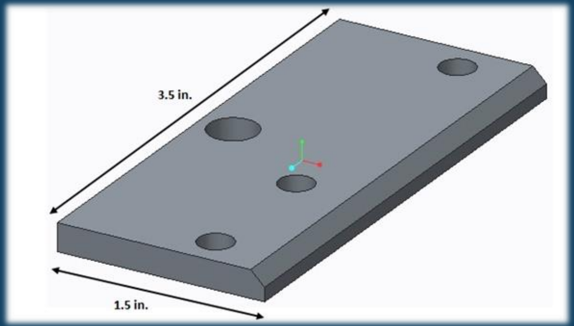


Figure 12. One side of clamp

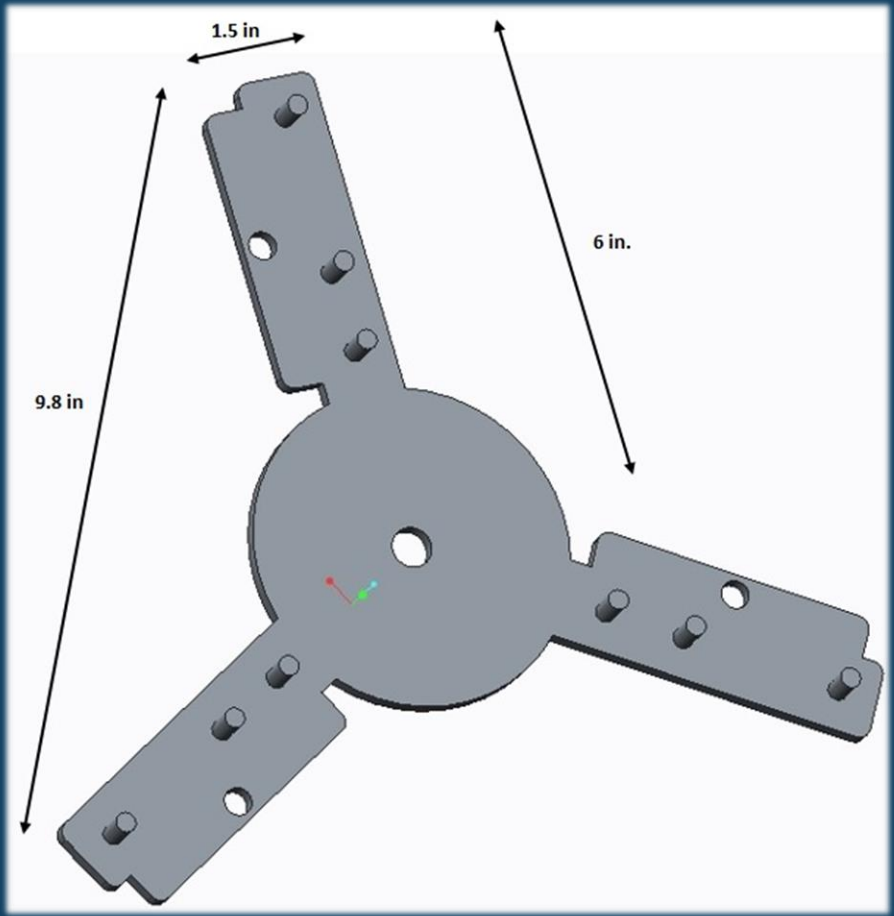


Figure 13. Clamp hub

- No tools needed
- Thumb screws reduce parts
- Waterjet and welding

Blade Connection (Chosen Design)

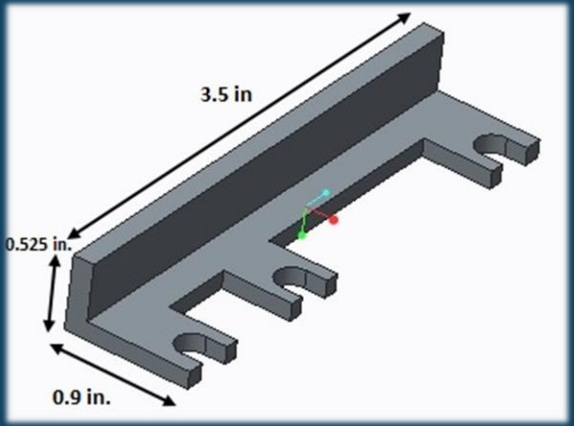


Figure 14. Tri-clip

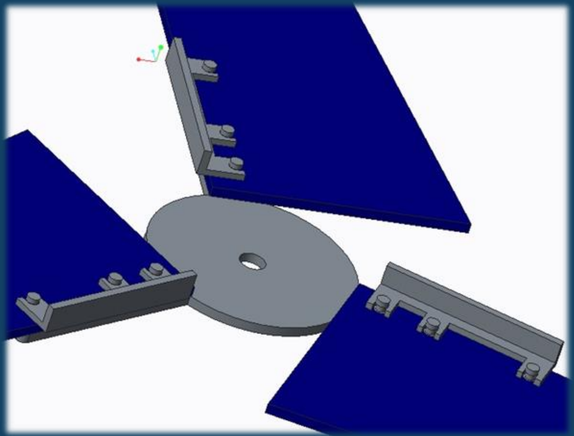


Figure 15. Clip design

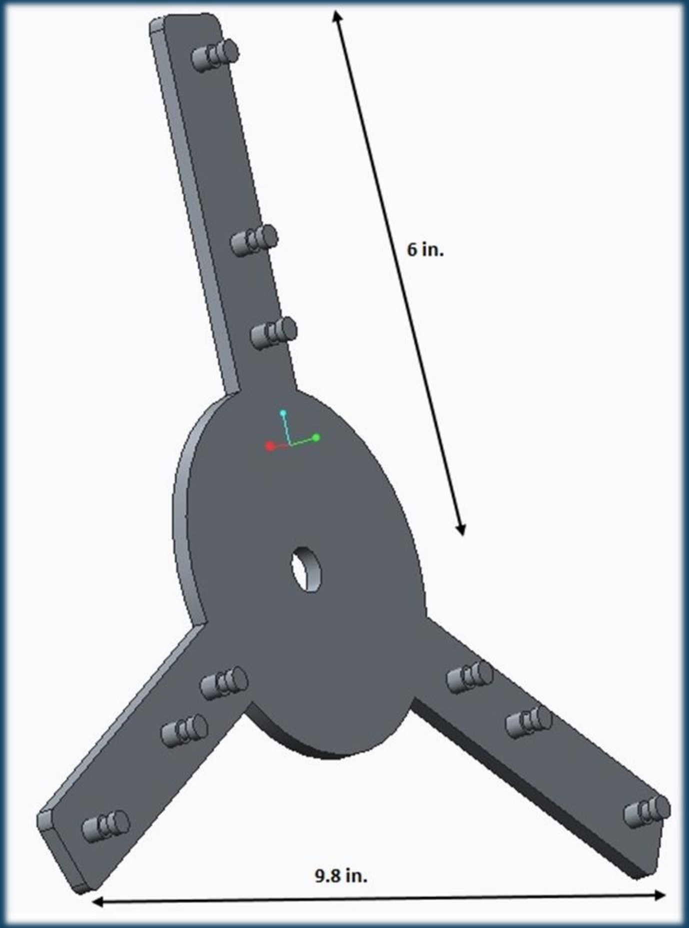


Figure 16. Clip hub

- Flexible, durable 1095 Spring Steel
- Variation of "e-clip"
- Groove and clip secure blade
- Cyclic loading tests, for failure.

Turbine Blades (Cont.)

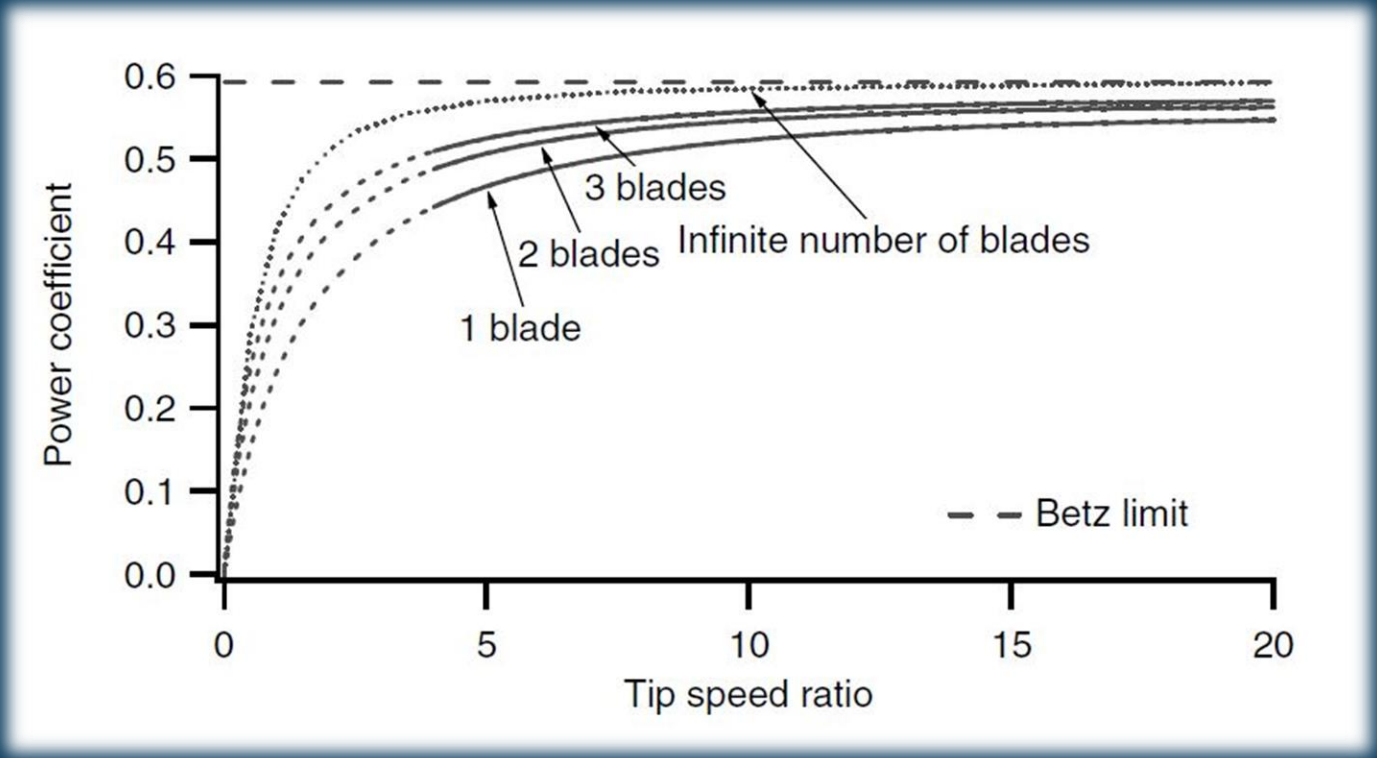


Figure 17. Power coefficient vs. TSR

$$Tip\ Speed\ Ratio\ (TSR) = \frac{\omega * R}{V_w}$$

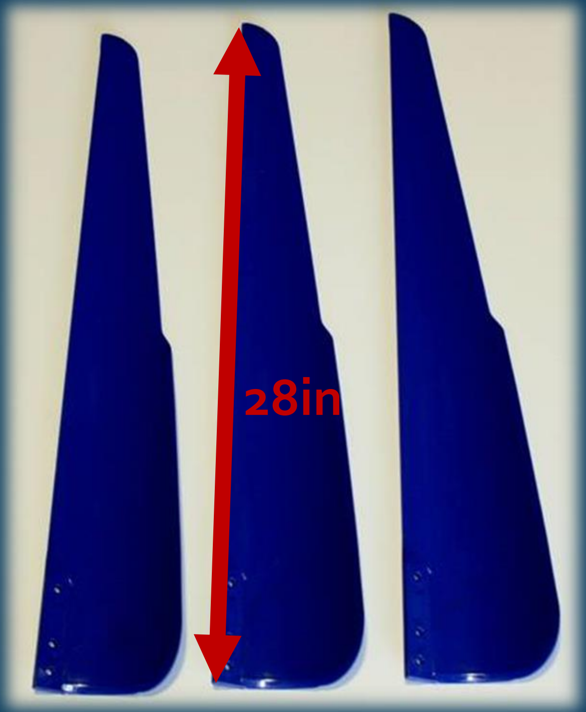


Figure 18. Selected blades.

ID	Task Name	Start	Finish
1	**Project Planning**	**Mon 8/31/15**	**Fri 9/25/15**
2	Meet Group and Advisor	Mon 8/31/15	Fri 9/11/15
3	Determine Contraints and Objective	Mon 9/14/15	Wed 9/16/15
4	Develop Need Statement	Mon 9/14/15	Tue 9/22/15
5	Create Schedule	Fri 9/11/15	Fri 9/25/15
6	**Conceptual Design**	**Mon 10/5/15**	**Fri 11/6/15**
7	Brainstorming	Mon 10/5/15	Fri 10/16/15
8	Evaluate Concepts	Mon 10/19/15	Fri 11/6/15
9	Select Concept	Mon 10/19/15	Fri 11/6/15
10	**Detailed Design**	**Mon 11/9/15**	**Tue 12/15/15**
11	Material Selection	Mon 11/9/15	Mon 11/23/15
12	Analysis	Tue 11/17/15	Tue 12/15/15
13	**Embodiment Design**	**Mon 11/30/15**	**Fri 4/22/16**
14	Select/Order parts	Mon 11/30/15	Fri 2/26/16
15	Construct Turbine	Thu 2/18/16	Wed 3/16/16
16	Test Turbine	Thu 2/18/16	Fri 4/22/16

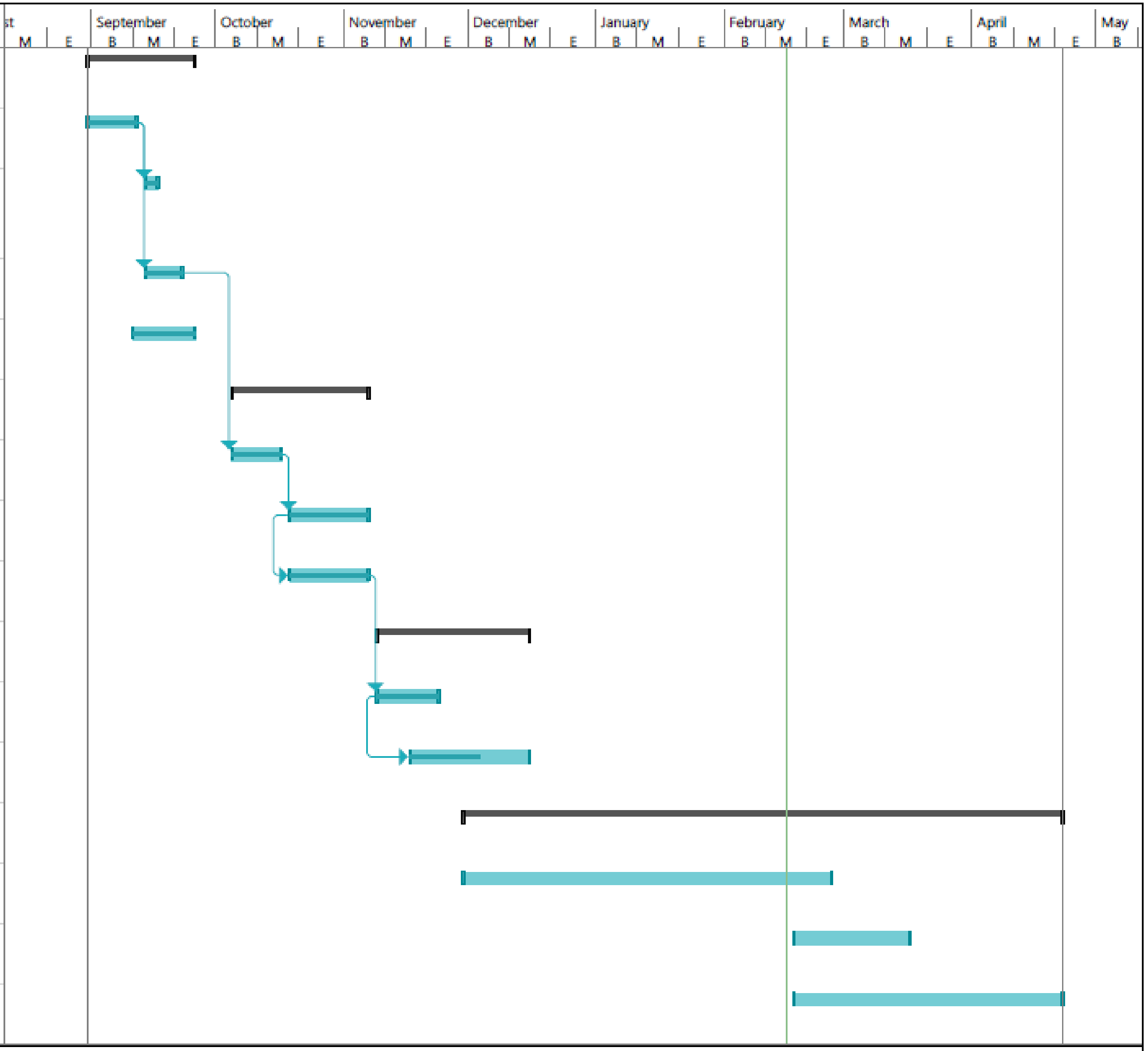
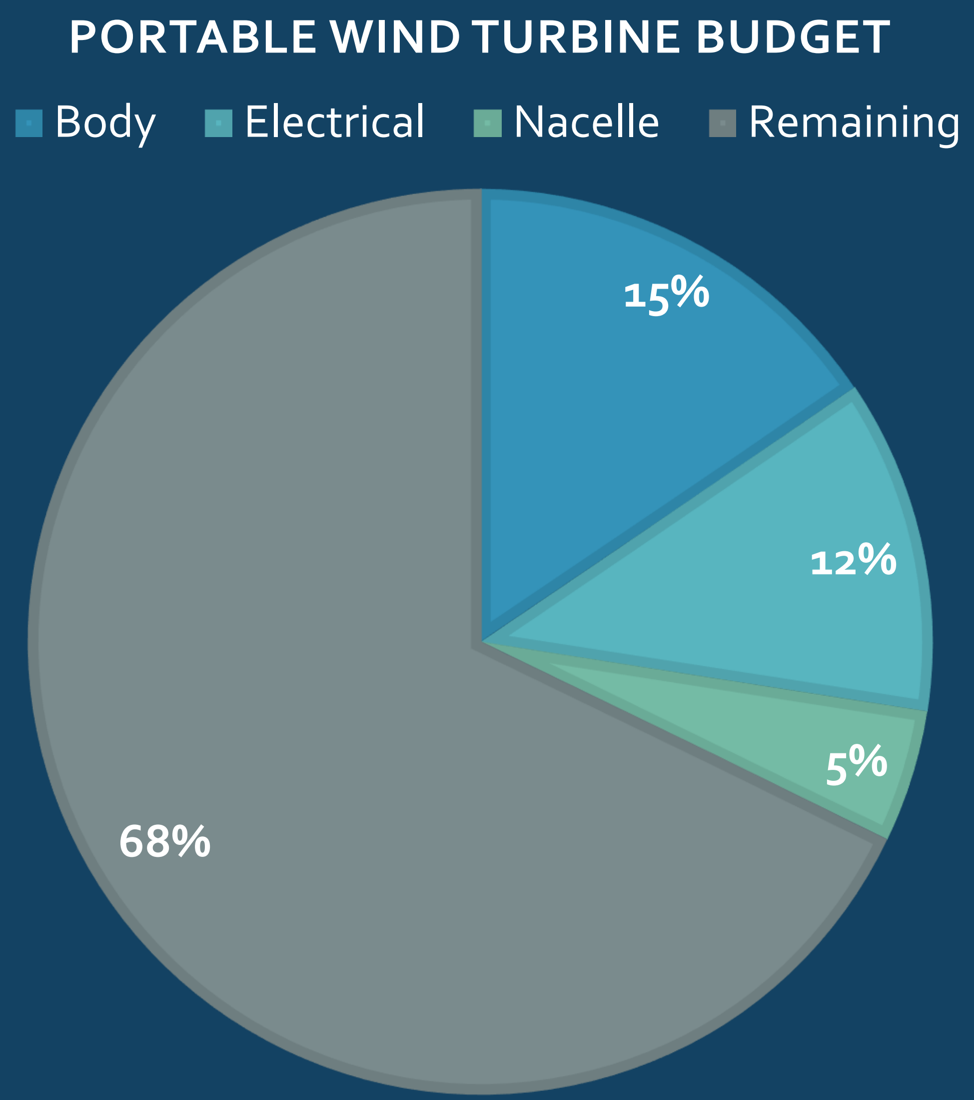


Figure 19. Team 15's Gantt Chart

Budget


PORTABLE WIND TURBINE BUDGET
Body
Electrical
Nacelle
Remaining
15%
12%
5%
68%

Moving Forward

- Electrical System
  - Test Generator Power Output
  - Final Selection of Parts
    - Charge Controller
    - Battery
- Base
  - Clamp Testing
  - Fabrication and Assembly of Parts
- Nacelle
  - Nacelle casing

References

1. Claremont. Stick Figure Drawing Checklist, Image, Web, Accessed Nov. 16, 2015. http://claremont.sd63.bc.ca/pluginfile.php/20101/mod_page/content/9/stick_figure_drawing_checklist_800_2328%20(1).jpg
2. Manwell, McGowan and A.L. Rogers. *Wind Energy Explained: Theory, Design and Application, 2nd Ed.* West Sussex, UK: John Wiley & Sons Ltd., 2009. PDF, pg 140.
3. WindyBlue Power, DC-540 Motor, Image, Web, Accessed Nov. 18, 2015. http://www.windbluepower.com/Permanent_Magnet_Alternator_Wind_Blue_Low_Wind_p/dc-540.htm
4. Clamp, Image, Web, Accessed February 10, 2016. https://www.rockwestcomposites.com/accessories/locking-mechanisms/telescoping-clamps/1403
5. Tripod Feet, Image, Web, Accessed Febuary 10, 2016. http://www.bhphotovideo.com/c/product/326244-REG/Gitzo_G1410_130B3_G1410_130B3_All_Terrain_Shoes.html/prm/alsVwDtl
6. WindyNation. 28in HyperSpin Aluminum Wind Turbine Generator Blades, Image, Web, Accessed Oct. 21, 2015. http://www.windynation.com/Blade-Sets/28-inch-HyperSpin-Aluminum-Wind-Turbine-Generator-Blades-Set-of-5/-/651?p=YzE9NQ
7. Rayleigh Distribution, Web, Accessed Dec. 3, 2015. https://upload.wikimedia.org/wikipedia/commons/thumb/a/a9/Rayleigh_distributionCDF.svg/325px-Rayleigh_distributionCDF.svg.png
8. PresenterMedia. Running Up Arrow Stairs, Image, Web, Accessed Oct. 21, 2015. http://www.presentermedia.com/index.php?target=closeup&maincat=clipart&id=5692

Questions?

Appendix

Calculations

Overturning Equations

- $W_{Min} = \frac{2F_W H}{L \sin \phi}$

- $F_W = \frac{W_T L \sin \phi}{2H}$

- If $W_T = 30lb$ and the over turning axis is the minimum distance,
  - $F_W = 6.55 \frac{m}{s}$ $(14.7\ mph)$
- If $W_T = 30lb$ and the over turning axis is over the extended foot,
  - $F_W = 9.26 \frac{m}{s}$ $(20.8\ mph)$

Maximum Angle of Legs (Phi)

To still account for a 15 degree slope and have 28 inch leg segments

- 2 axis that could require slop adjustment
  - A. 2 legs parallel on slope with one extended away
    - Maximum angle: 55.44 degrees
  - B. 1 leg on slope with other 2 legs extended away
    - Maximum angle: 60.45 degrees
- Neither calculation accounted for the additional leg length caused by:
  - Need for welded piece to exceed 2”
    - Right now accounting for complete overlap. Will not be.
  - Feet adding to the 56 inch leg length
- Additional leg length causes slightly lower maximum angles of legs
  - Since the adjustable part remains constant at 26 inches.
- Max angle if actual leg length increases 2 inches to 56 inches:
  - A. 53.80 degrees
  - B. 59.13 degrees
- Conservatively, choose 50 degrees
  - Tripods on the market use 30 degrees as their angle.

Maximum Angle of Legs (Phi) Equations

- A. $$\frac{3\times L\times \sin\left(\tan^{-1}\left(\frac{\tan\phi}{2}\right)\right)\times \tan\theta\times \sin(90-\theta)}{\sin\left(90+\theta-\tan^{-1}\left(\frac{\tan\phi}{2}\right)\right)}=\Delta L$$

- B. $$\frac{3\times L\times \sin(\phi)\times \tan\theta\times \sin(90-\theta)}{\sin(90+\theta-\phi)}=\Delta L$$

- Where all angles are in degrees, Theta is the slope, Phi is the angle of the legs from the vertical, L is the length of the legs, and Delta L is the length that the legs are able to adjust.

Failure of Members

- *Due to Stress*
  - $\sigma = \sigma_{Axial} + \sigma_{Bending}$
  - $\sigma_{Axial} = \frac{F}{A}$
  - $\sigma_{Bending} = \frac{Mc}{I}$
- Due to Buckling
  - $P_{cr} = \frac{\pi^2 EI}{k^2 L^2}$
- Variables
  - $E_{alum} = 10{,}000\ ksi$ $\sigma_{y_{alum}} = 35\ ksi$ $I_{pipe} = \left(\frac{\pi\left(d_0^4 - d_i^4\right)}{64}\right)$
  - $k_{neck} = 2.0$ $k_{leg} = 0.7$ $c = \frac{d_0}{2}$
  - $L_{leg} = 26\ inches$ $L_{neck} = 26\ inches$

Failure of Legs Equations

- Stress:
  - $\sigma_{legs_{roller}} = \left(\frac{\left(W_T + 2F_W \frac{H}{L \sin \phi}\right) L \sin \phi}{3} \frac{d_0}{2} \frac{64}{\pi\left(d_0^4 - d_i^4\right)} \right) + \left(\frac{4\left(W_T + 2F_W \frac{H}{L \sin \phi}\right) \cos \phi}{3\pi\left(d_0^2 - d_i^2\right)} \right)$
  - $\sigma_{legs_{pin}} = \left(\left(\frac{F_W \cos \phi - \left(W_T + 2F_W \frac{H}{L \sin \phi}\right) \sin \phi}{3} \right) L \frac{d_0}{2} \frac{64}{\pi\left(d_0^4 - d_i^4\right)} \right) + \left(\frac{4\left(W_T + 2F_W \frac{H}{L \sin \phi}\right) \cos \phi}{3\pi\left(d_0^2 - d_i^2\right)} \right)$
- Buckling:
  - $W_{Max} = \frac{\left(\frac{\pi^2 EI}{k^2 L_{leg\ seg.}^2}\right) - \left(\frac{2F_W}{3 \sin \phi}\right)}{3 \cos \phi}$

Failure of Neck Equations

- Bending
  - $\sigma_{Neck} = \left(\frac{(H - L\cos\phi) F_W \frac{d_0}{2}}{\left(\frac{\pi \left(d_0^4 - d_i^4 \right)}{64} \right)} \right) + \left(\frac{4 W_N}{\pi \left(d_0^2 - d_i^2 \right)} \right)$
- Buckling
  - $W_{Max} = \frac{\pi^2 E I}{k^2 {L_{neck}}^2}$

‘Bump’ Load

- Where the Nacelle is ‘bumped’ and is offset a distance.
  - Checked against overturning
- $W_{Min} = \frac{F_W\left(H\cos\theta + \frac{L}{2}\sin\phi\sin\theta\right)}{\left(\frac{L}{2}\sin\phi\cos\theta - H\sin\theta\right)}$
- $F_{W_{Max}} = \frac{W_T\left(\frac{L}{2}\sin\phi\cos\theta - H\sin\theta\right)}{\left(H\cos\theta + \frac{L}{2}\sin\phi\sin\theta\right)}$
- $\theta = \sin^{-1}\left(\frac{Offset\ Distance}{H + \frac{L}{2}\sin\phi}\right)$
- Maximum offset ‘bump’ distance under normal conditions:
  - 15.55 inches (at center of nacelle)
    - 8 inches was goal
    - Equivalent to having the turbine on a 9 degree sloped surface (max slope under normal conditions)

Shear Calculations

- $\tau = \frac{V}{A}$
- Due to Pins on Tube
  - Negligible
  - $\tau_{tube} = \frac{V}{d_0 L_{leg\ seg.}}$
- Due to Tube on Pins
  - Still Negligible, though significantly larger, depending on selected pin size.
  - $\tau_{pin} = \frac{V}{\left(\frac{\pi\left(d_0^2 - d_i^2\right)}{4}\right)}$