Solar Tracking Structure Project Proposal

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Overview

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  o Competition
• Concept Generation and Selection
  o Dual Axis: Modified TIE Fighter
  o Nitinol solar tracker
• Final Design
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• Conclusion
What is Solar Energy?

- Photovoltaic cells take solar energy and turn it into usable electrical energy by means of the Photoelectric Effect [1].

- PV cells operate at maximum efficiency when pointed directly at the sun. But, solar tracking can be expensive and require a lot of maintenance.
Introduction

• Need Statement:
  o “Photovoltaic Cells are less productive when not pointed directly at the sun.”

• Project Goal:
  o “Design a system that maximizes amount of sun being absorbed while minimizing the cost of operation and maximizing the reliability.”
### Objectives

<table>
<thead>
<tr>
<th>Objectives</th>
<th>Measurement Basis</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inexpensive</td>
<td>Unit cost of production</td>
<td>$</td>
</tr>
<tr>
<td>Supported weight</td>
<td>Stress vs. Strain</td>
<td>N/m²</td>
</tr>
<tr>
<td>Low Maintenance</td>
<td>Time until part replacement</td>
<td>Days</td>
</tr>
<tr>
<td>Display power output</td>
<td>Digital screen</td>
<td>Amp/hour</td>
</tr>
<tr>
<td>Track the sun</td>
<td>Rotation angle</td>
<td>° Degrees</td>
</tr>
</tbody>
</table>
About the Client

• Dr. Thomas Acker
  o Professor of Mechanical Engineering at Northern Arizona University.
  o Worked at the National Renewable Energy Laboratory (03-04)
  o Director of Sustainable Energy Solutions (SES).
  o Gained NAU over $25 Million in research grants.

• Why is he sponsoring this project?
  o Collect more energy for storage.
  o To teach about renewable energy.
The WERC Competition

- WERC: A Consortium for Environmental Education and Technology Development competition
- At New Mexico State University in Las Cruces, N.M. It’s run by the Institute for Energy & the Environment (IEE).
- Task 3 – Power Point Tracking for Solar Energy
  - First Place Award per task $2,500

Our team will develop a novel system for maximum power point tracking and demonstrate its cost effectiveness by measuring the additional power generation vs. the cost of the components and power required for operation.
Initial Design 1: Ni-Ti

• Nitinol Based
  o A shape memory alloy; Nitinol contracts in length when heated either through an induced current or external heating.

• Difficulties:
  o One directional motion.
  o Expensive.
  o Requires some form of movement locking to not waste energy
Initial Design 2 - Mod. TIE Fighter

• Dual Axis
  o Motor-operated primary
  o Manually operated secondary

• Difficulties
  o Cost vs. efficiency
  o Potential tipping
Decision Criteria

- Supported weight: weight (pounds) that the structure can support
- Cost: $ for parts and installation
- Efficiency: Energy generated
- Area: Space needed to operate tracking structure
- Reliability: System consistency, incorporates maintenance (life of parts)
## Decision Matrices

### Design Decision Matrix

<table>
<thead>
<tr>
<th>Scale: 0-1-2-3-4</th>
<th>Criterion Weight</th>
<th>Nickel Titanium</th>
<th>Tie Fighter</th>
<th>Rotisserie</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supported Weight (lbs)</td>
<td>0.14</td>
<td>3</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Cost (S)</td>
<td>0.29</td>
<td>4</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Efficiency (%)</td>
<td>0.21</td>
<td>2</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Area (ft*ft)</td>
<td>0.07</td>
<td>3</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Reliability (%)</td>
<td>0.29</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td>1</td>
<td>2.79</td>
<td>3</td>
<td>3.29</td>
</tr>
</tbody>
</table>
Chosen Design

The Rotisserie

- Single Axis Tracker
- Keeps rotating axis through center of gravity
- Potential for second axis
Rotisserie Key Stresses

- Support Rod
- Hinge Bolt
- Holding Frame
- Frame Weld
Maximum Stresses in Analysis

- Snow load
  - Assume 3 feet of snow over entire panel
  - Load = **198 lbs**

- Wind Load
  - $F = 0.00256V^2CdA$ [2]
  - Assumed 65 mph winds
  - Load = **210 lbs**
# Engineering Analysis Results

<table>
<thead>
<tr>
<th>Stresses</th>
<th>Material</th>
<th>Yield Str (Ksi)</th>
<th>Max Stress (Ksi)</th>
<th>FOS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hinge Bolt (0.5&quot;)</td>
<td>Steel</td>
<td>70</td>
<td>5.03</td>
<td>7.0</td>
</tr>
<tr>
<td>Support Bar (1.5&quot;)</td>
<td>AISI1010</td>
<td>60</td>
<td>5.261</td>
<td>11.4</td>
</tr>
<tr>
<td>Frame (1/8&quot;)</td>
<td>AISI1010</td>
<td>60</td>
<td>30.57</td>
<td>2.9</td>
</tr>
<tr>
<td>Frame connection</td>
<td>Weld</td>
<td>50</td>
<td>17.5</td>
<td>2.9</td>
</tr>
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</table>
Cost Analysis

<table>
<thead>
<tr>
<th>Cost Analysis</th>
<th>Units</th>
<th>Comment</th>
<th>Cost/unit</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor</td>
<td>1</td>
<td>Antennacraft TDP-2</td>
<td>$62.99</td>
<td>$62.99</td>
</tr>
<tr>
<td>Bearing</td>
<td>2</td>
<td>TB-105 Support</td>
<td>$35.95</td>
<td>$71.90</td>
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<tr>
<td>Axle Bolt</td>
<td>2</td>
<td>0.5&quot; x 4&quot;</td>
<td>$2</td>
<td>$4.00</td>
</tr>
<tr>
<td>1.5&quot; Pipe Flange</td>
<td>2</td>
<td>Home Depot</td>
<td>$2</td>
<td>$4.00</td>
</tr>
<tr>
<td>2&quot; Pipe Flange</td>
<td>2</td>
<td>Home Depot</td>
<td>$2</td>
<td>$4.00</td>
</tr>
<tr>
<td>Flang Bolt</td>
<td>16</td>
<td>Home Depot</td>
<td>$0.75</td>
<td>$12.00</td>
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<tr>
<td>Pipe Hinge</td>
<td>2</td>
<td>Still Shopping</td>
<td>$10</td>
<td>$20.00</td>
</tr>
<tr>
<td>2&quot; Base Pipe</td>
<td>1</td>
<td>8 ft, cut down</td>
<td>$35</td>
<td>$35.00</td>
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<tr>
<td>1.5&quot; Support pipe</td>
<td>1</td>
<td>7 ft</td>
<td>$35</td>
<td>$35.00</td>
</tr>
<tr>
<td>1/8&quot; x 2.5&quot; Flat bar</td>
<td>1</td>
<td>13 ft at $9/72&quot;</td>
<td>$19.50</td>
<td>$19.50</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>$268.39</strong></td>
</tr>
</tbody>
</table>
Cost of Operation

- Motor Provides 8 ft*lbs of torque using 65 Watt
- Assuming operating conditions of 5° intervals throughout the course of the day:

\[
\frac{360°}{\text{day}} / \frac{5.14°}{\text{s}} = 70 \text{ s/day}
\]

Factoring time to start motor = 80 s/day

= 8 hrs/year

At 65 Watts, gives 0.52 kWh/year

Assuming max price of electricity in United States: $0.17/ kWh [1]

Cost of operation = $0.09/ year
Life Cost

161 Days of Full Sun per year (100%) = 11.9 hours/ day of sun
102 Days of semi-cloudy (70%) = 8.31 equivalent hours / day
101 Days of mostly cloudy (40%) = 4.75 equivalent hours/ day
Total of **3255.2 hrs** of sun/ year

Dual Axis gives 423.2 kWh/year = $50.78/year Generated
Single Axis gives 391.92 kWh/year = $47.03/year Generated
Fixed Axis gives 302.28 kWh/year = $36.27/year Generated

$10.75/ year by switching to single axis = **24.9 years to pay off**
# Team Schedule

<table>
<thead>
<tr>
<th>Name</th>
<th>Begin date</th>
<th>End date</th>
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<tbody>
<tr>
<td>Prototype</td>
<td>1/13/14</td>
<td>1/23/14</td>
</tr>
<tr>
<td>Build Prototype</td>
<td>1/13/14</td>
<td>1/23/14</td>
</tr>
<tr>
<td>Test Prototype</td>
<td>1/21/14</td>
<td>1/23/14</td>
</tr>
<tr>
<td>Construct Final Design</td>
<td>1/24/14</td>
<td>2/26/14</td>
</tr>
<tr>
<td>Supporting Frame</td>
<td>1/24/14</td>
<td>2/14/14</td>
</tr>
<tr>
<td>Attach Flanges To Pipe</td>
<td>2/17/14</td>
<td>2/18/14</td>
</tr>
<tr>
<td>Attach Motor</td>
<td>2/18/14</td>
<td>2/21/14</td>
</tr>
<tr>
<td>Attach Panel</td>
<td>2/24/14</td>
<td>2/25/14</td>
</tr>
<tr>
<td>Test</td>
<td>2/27/14</td>
<td>3/5/14</td>
</tr>
<tr>
<td>Test Final Design</td>
<td>2/27/14</td>
<td>3/5/14</td>
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<tr>
<td>Competition Due Dates</td>
<td>1/7/14</td>
<td>4/7/14</td>
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<tr>
<td>Contest Registration</td>
<td>1/7/14</td>
<td>1/7/14</td>
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<tr>
<td>Entry Fee</td>
<td>1/14/14</td>
<td>1/14/14</td>
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<tr>
<td>Safety Summary, MSDS Sheets, and Flow Sheet</td>
<td>3/19/14</td>
<td>3/19/14</td>
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<tr>
<td>Written Report</td>
<td>3/21/14</td>
<td>3/21/14</td>
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<tr>
<td>Equipment Transportation Form</td>
<td>3/28/14</td>
<td>3/28/14</td>
</tr>
<tr>
<td>Opening Ceremonies/Safety Meeting</td>
<td>4/7/14</td>
<td>4/7/14</td>
</tr>
</tbody>
</table>
Concluding Statements

• Our client is Dr. Thomas Acker, a Professor at NAU with a lot of background in sustainable energies.

• Problem Statement:
  1. Solar cells need an inexpensive, efficient way to be turned to track the sun across the sky.

• The project goal is to design a system that:
  1. Maximizes the amount of sun being absorbed.
  2. Minimizes the cost of operation.
  3. Maximizes the reliability.

• Competition specifications are still developing.
Concluding Statements (cont.)

• Previous designs
  1. Nitinol is not reliable enough
  2. Efficiency of TIE fighter does not justify increase in price

• Final chosen Design- The Rotisserie
  1. Room for an added axis
  2. Lowest factor of safety 2.9 on the frame, assuming high wind and max snow load.
  3. $268 dollars initial cost per panel
  4. Theoretically under $0.10 per year to run.

• Schedule moving on to phase two: pre-construction
References


Questions ?