ISES Solar Charging Station

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Overview

• The need and goal
• Objectives and constraints
• Previous designs
• Decision matrices
• Engineering analysis
• Final Design
• Cost analysis
• Progress
• Conclusion
Introduction

• Sponsor is Dr. Thomas Acker
• Design a Solar charging station that can charge small electronic devices
• Two main subsections to the solar charging station
  • Control systems
  • Display systems
The Need

• Northern Arizona University currently does not have a place that uses a sustainable, renewable energy source, that students and faculty could use in order to charge small electronic devices.

Goal

• Design a solar charging station capable of providing enough power to charge small electronic devices.
### Objectives

**Primary project objectives with measurement basis**

<table>
<thead>
<tr>
<th>Objective</th>
<th>Measurement Basis</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charge Small Devices</td>
<td>Total power output</td>
<td>kW</td>
</tr>
<tr>
<td>Inexpensive</td>
<td>Cost of the system</td>
<td>$</td>
</tr>
<tr>
<td>Educational</td>
<td>A digital readout to inform users of power output</td>
<td>kW</td>
</tr>
<tr>
<td>Maximize power output</td>
<td>Total power output</td>
<td>kW</td>
</tr>
<tr>
<td>Withstand Environment</td>
<td>Determine the total stress experienced by the system</td>
<td>kPa/psi</td>
</tr>
</tbody>
</table>
Operating Environment

• Target Location: W.A. Franke College of Business (Patio), NAU.
• Mostly sunny throughout the day
• Able to withstand:
  • Rain
  • Snow
  • Hail
  • High Winds
Constraints

• Building Codes
• Electrical Codes
• Number of usable solar panels
• Weather conditions
## Quality Function Deployment Diagram

<table>
<thead>
<tr>
<th>Customer Requirements</th>
<th>Educational</th>
<th>Withstand Environment</th>
<th>Charge Small Devices</th>
<th>Safety</th>
<th>Inexpensive</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Units</td>
<td>kW</td>
<td>kWhr</td>
<td>kPa</td>
<td>$</td>
<td>kPa</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>36</td>
<td>x</td>
<td>1000</td>
<td>x</td>
</tr>
</tbody>
</table>

Thomas Penner
House of Quality

- Power
- Energy
- Stress
- Cost
- Yield Strength
- Weight

House of Quality
Control System 1

**Advantages**
- Least expensive option
- Fewest components needed

**Disadvantages**
- Energy losses from batteries not in operation
- Battery replacement over time

Figure provided by Home Power
Control System 2

Advantages
- Can be used anytime during the day
- Extra energy goes into the grid to save money

Disadvantages
- Does not work at night during power failure
- Does not save money at night
Control System 3

Advantages
- Can still be used during a power outage

Disadvantages
- Complicated to get everything to work properly
- Battery replacement
- The most expensive option

Grid tie with battery backup control system

Figure provided by Endecon Engineering
Display System 1

Pre-Programmed Display

**Advantages**
- Variety of interactive displays
- Most appealing display

**Disadvantages**
- Price

Figure provided by GEO
Display System 2

Team Programmed Display
- Code is written by team to display power measurements

Advantages
- Cheapest display solution

Disadvantages
- Requires time to program
- Display is limited to simplistic designs

Figure provided by HVG Engineering
Display System 3

Tablet Display
• Data is transmitted wirelessly to the tablet

Advantages
• Complete customization

Disadvantages
• Specialized application programing
• Expensive

Figure provided by Google
Design Criteria

• Cost- How expensive the system is
• Efficiency- Power savings
• Simplicity- How easy the system is to build
• Reliability- Operates under various circumstances
• Environmentally Friendly- how the design impacts the environment
• Customization- The various features of the display
• Man Hours- The amount of time required
• Adaptability- How compatible the system is
## Decision Matrix

**Decision matrix for solar control systems**

<table>
<thead>
<tr>
<th>Decision Criteria</th>
<th>Decision Criteria Weights</th>
<th>Grid Only</th>
<th>Battery Only</th>
<th>Grid with Battery Backup</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>0.10</td>
<td>3</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Efficiency</td>
<td>0.30</td>
<td>5</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Simplicity</td>
<td>0.10</td>
<td>3</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Reliability</td>
<td>0.40</td>
<td>5</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Environmentally Friendly</td>
<td>0.10</td>
<td>4</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>4.5</td>
<td>3.1</td>
<td>3.4</td>
</tr>
</tbody>
</table>
### Decision Matrix

#### Decision matrix for the display options

<table>
<thead>
<tr>
<th>Decision Criteria</th>
<th>Decision Criteria Weights</th>
<th>Pre-Programmed</th>
<th>Team Programmed</th>
<th>Tablet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>0.05</td>
<td>3</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Reliability</td>
<td>0.40</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Customization</td>
<td>0.15</td>
<td>4</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Man Hours</td>
<td>0.10</td>
<td>5</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Adaptability</td>
<td>0.30</td>
<td>4</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>4.05</strong></td>
<td><strong>3.55</strong></td>
<td><strong>1.75</strong></td>
<td></td>
</tr>
</tbody>
</table>
PV Panel

- PV panel angled at 35°
- 7 ASE-300-DG/50 panels
- PV panel are placed at 35° facing due south
- All of the engineering analysis followed are calculated based on this orientation
Irradiance

- The irradiance is based on the ideal irradiance of 1000W/m², the zenith angle, declination angle, hour angle and latitude of Flagstaff.
- The zenith angle is the angle between the vertical and the line to the sun.
- The declination angle is the angle between the equator and a line drawn from the center of the Earth to the center of the sun.
Percent Loss

- Percent loss represents the energy loss due to high temperature
- The percent loss increases during the summer months because it gets hotter during that time due to a more prolonged exposure to sunlight
- \( T_{cell} = T_{air} + \frac{NOC_T - 25}{800} \times \text{Irradiance} \)
- \( \text{Percent loss} = (T_{cell} - 25) \times TCoP \)
- NOCT is the nominal operating cell temperature
- TCoP is the temperature coefficient of power
- TCoP = 0.47 % per °C
Power

- The power output is determined based off of the irradiance going into the PV panel, and the losses experienced by the panel
- \[ P = \text{Irradiance} \times 0.19 \times (1 - \text{percent loss}) \times (1 - 0.05) \]
- The 0.19 is the efficiency of solar panel
- The 0.05 takes into account dust and dirt build up on the panels.
Energy

- Maximum is 6.18 MJ
- Minimum is 1.43 MJ
- Average is 3.86 MJ
Charging Devices

• 6 laptops at 40W
• 6 cell phones at 4W
• A total of 264W is required to power all the devices simultaneously
• All devices should be capable of charging for 8 hours
• A total of 2112W-hours is required per day
Battery Analysis

• The system requires 2112 Watt-hours per day

\[
\frac{\text{Watt-hours}}{\text{day}} \times \text{days of autonomy} \times \frac{1}{\text{depth of discharge}} = \text{total amount of watt-hours}
\]

• Battery Bank Capacity = 9716 watt hours / 203 amp hours
• A 12V / 245Ah AGM Battery was selected
• Four batteries will be wired in series to achieve a system voltage of 48V
Charge Controller

• Regulates the power from the solar panels to the batteries

\[ \text{Amps}_{\text{req}} = \frac{\text{Power}_{\text{panels}}}{\text{Voltage}_{\text{batteries}}} \]

\[ \text{Amps}_{\text{req}} = \frac{792\text{W}}{48\text{V}} = 16.5\text{A} \]

• A charge controller of 20 amps will satisfy our specifications
Final Design

• Grid Tied control system
• The 7 solar panels are wired in series
• Max Power = 350Amp
  • #12 AWG wiring sizing

• Murray 20-Amp Single Pole AC disconnect positioned after the inverter
Inverter and Combiner Box

• Samlex 1000W Pure Sine Inverter
  • Efficiency = 96.7%
  • Max Input Power = 500V

• OutBack Power PV Combiner Box FWPV-12 PV
  • Combines solar arrays into one feed
  • Integrated DC disconnect
  • Design to survive an outdoor environment
Metering Display

• Green Energy Options Chorus PV monitoring system
• Displays generation and consumption of electricity
• Accuracy of +/- 5%
• Power consumption is < 1 Watt
• Product life expectancy is 10 years
## Cost

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outlets</td>
<td>19.49</td>
</tr>
<tr>
<td>Inverter</td>
<td>416.67</td>
</tr>
<tr>
<td>Wires (50ft)</td>
<td>35.99</td>
</tr>
<tr>
<td>AC Disconnect</td>
<td>11.39</td>
</tr>
<tr>
<td>Combiner Box</td>
<td>145.53</td>
</tr>
<tr>
<td>USB cables (phones)</td>
<td></td>
</tr>
<tr>
<td>Android</td>
<td>29.95</td>
</tr>
<tr>
<td>Apple (2x)</td>
<td>29.95</td>
</tr>
<tr>
<td>Windows</td>
<td>3.95</td>
</tr>
<tr>
<td>USB cables (laptops)</td>
<td></td>
</tr>
<tr>
<td>Apple</td>
<td>38.95</td>
</tr>
<tr>
<td>HP/Dell</td>
<td>9.22</td>
</tr>
<tr>
<td>Acer</td>
<td>8.22</td>
</tr>
<tr>
<td>Sony</td>
<td>28.95</td>
</tr>
<tr>
<td>(leave two open for people to plug in their laptops)</td>
<td></td>
</tr>
<tr>
<td>Display</td>
<td>320.19</td>
</tr>
<tr>
<td>Total</td>
<td>$1128.40</td>
</tr>
</tbody>
</table>

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**Tyler Faulkner**
Gantt Chart

Project Progress

Alexa Kearns
Conclusion

The best overall system includes:

• A pre-programmed display is the best system for displaying power readings because of the efficient technology and competitive pricing.

• A grid tie control system is the optimal choice because it saves money and is the most reliable.

• The station will be capable of charging 6 laptops and 6 cell phones simultaneously.
Conclusion

• The PV panel is going to be angled at 35° facing due south to maximize performance.
• A 1000W inverter will be used to allow for unanticipated loads.
• The estimated budget will be $1128.40
References


References


Questions?