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

Objective	Measurement Basis	Units
Charge Small Devices	Total power output	kW
Inexpensive	Cost of the system	$
Educational	A digital readout to inform users of power output	kW
Maximize power output	Total power output	kW
Withstand Environment	Determine the total stress experienced by the system	kPa/psi

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

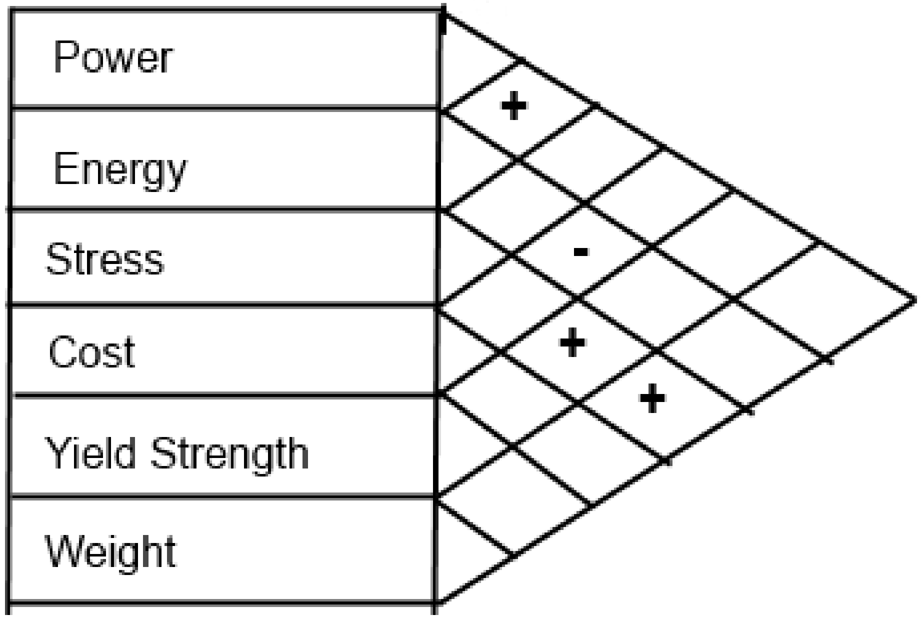
QFD

Quality Function Deployment Diagram

		Power	Energy	Stress	Cost	Yield Strength	Weight
Customer Requirements	Educational				x		
	Withstand Environment	x	x		x		x
	Charge Small Devices	x	x				
	Safety			x	x	x	x
	Inexpensive				x		
Units		kW	kWhr	kPa	$	kPa	N
		3	36	x	1000	x	x

House of Quality

House of Quality



Control System 1

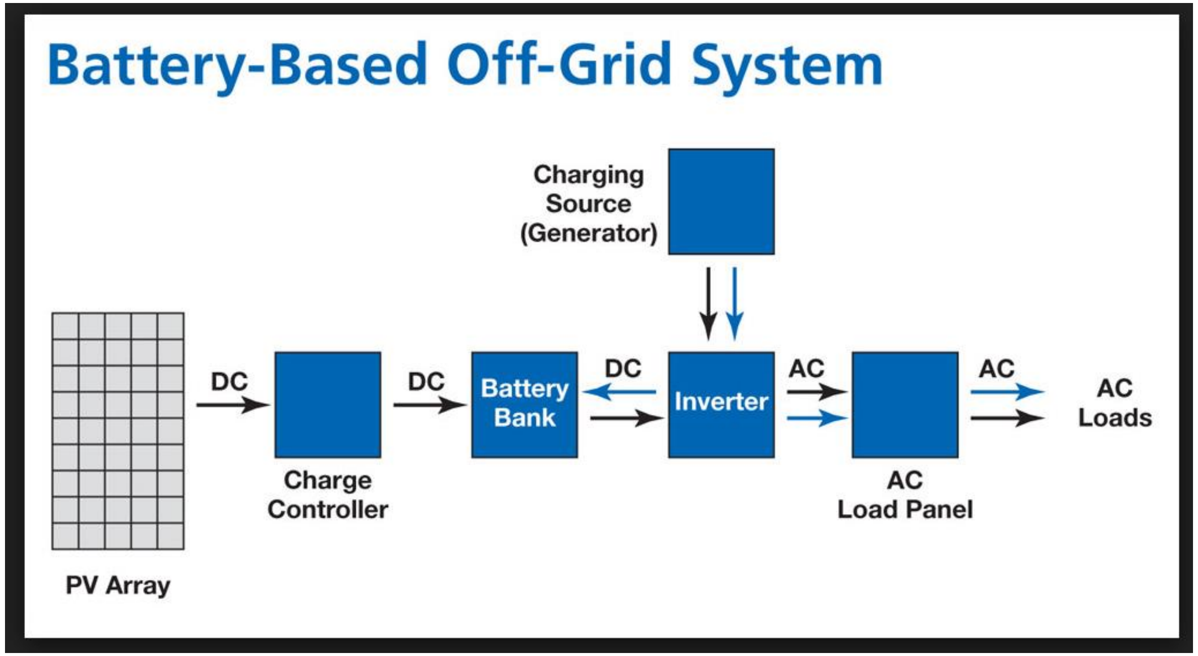


Figure provided by Home Power

Advantages

- Least expensive option
- Fewest components needed

Disadvantages

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

Control System 2

Grid tie control system

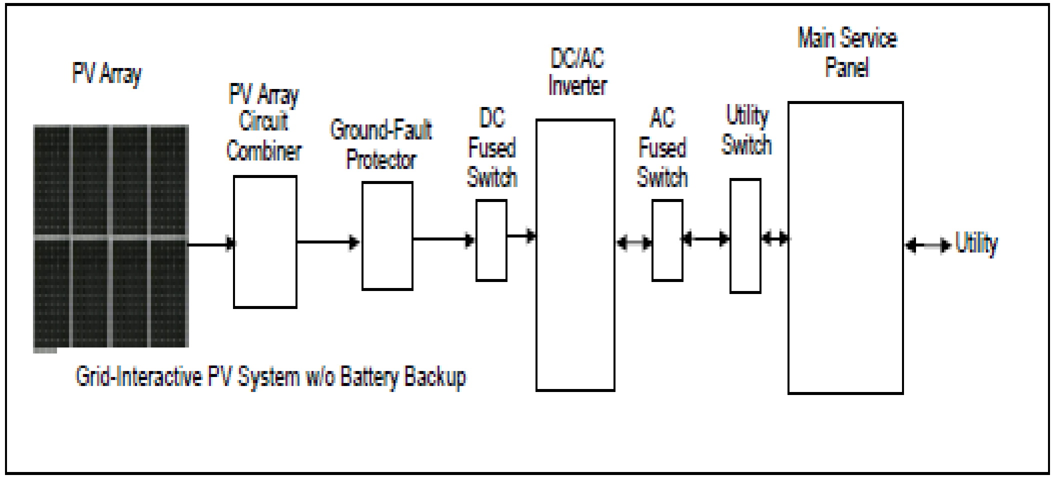


Figure provided by Endecon Engineering

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

Grid tie with battery backup control system

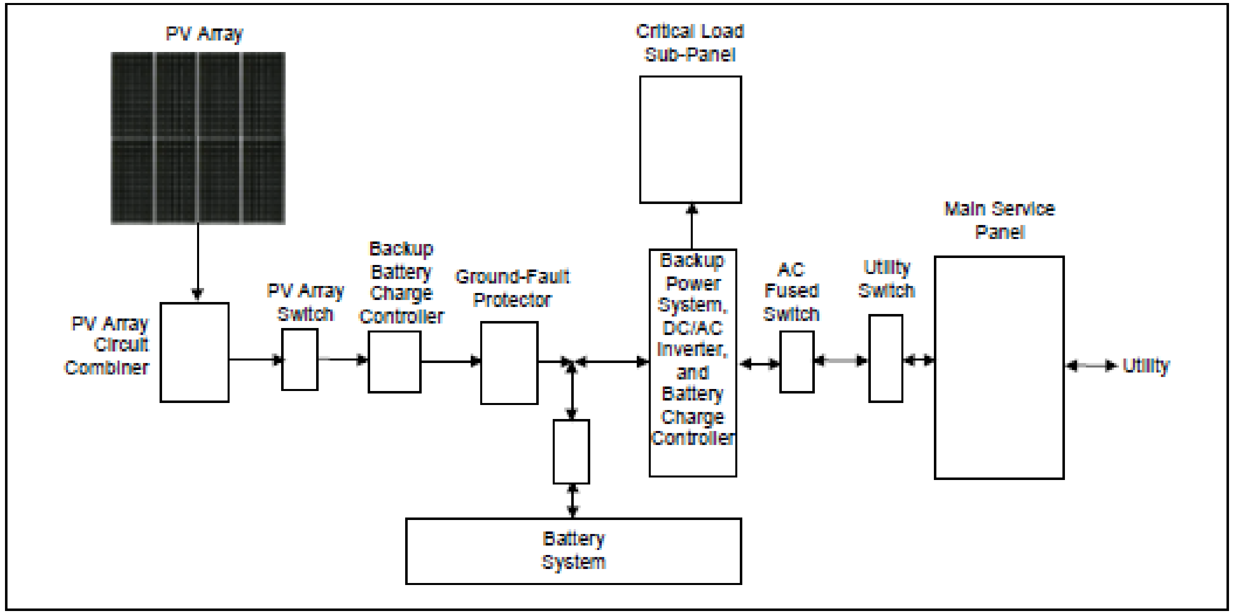


Figure provided by Endecon Engineering

Advantages

- Can still be used during a power outage

Disadvantages

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

Display System 1

Pre-Programmed Display

Advantages

- Variety of interactive displays
- Most appealing display

Disadvantages

- Price

GEO Chorus PV

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

Basic power display

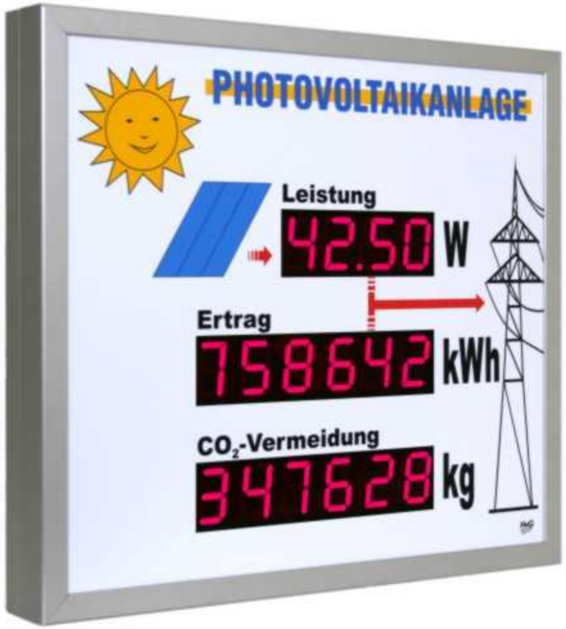


Figure provided by HVG Engineering

Display System 3

Nexus 7

Figure provided by Google

Tablet Display

- Data is transmitted wirelessly to the tablet

Advantages

- Complete customization

Disadvantages

- Specialized application programing
- Expensive

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

Decision Criteria	Decision Criteria Weights	Grid Only	Battery Only	Grid with Battery Backup
Cost	0.10	3	4	2
Efficiency	0.30	5	3	4
Simplicity	0.10	3	4	2
Reliability	0.40	5	3	4
Environmentally Friendly	0.10	4	2	2
Total		4.5	3.1	3.4

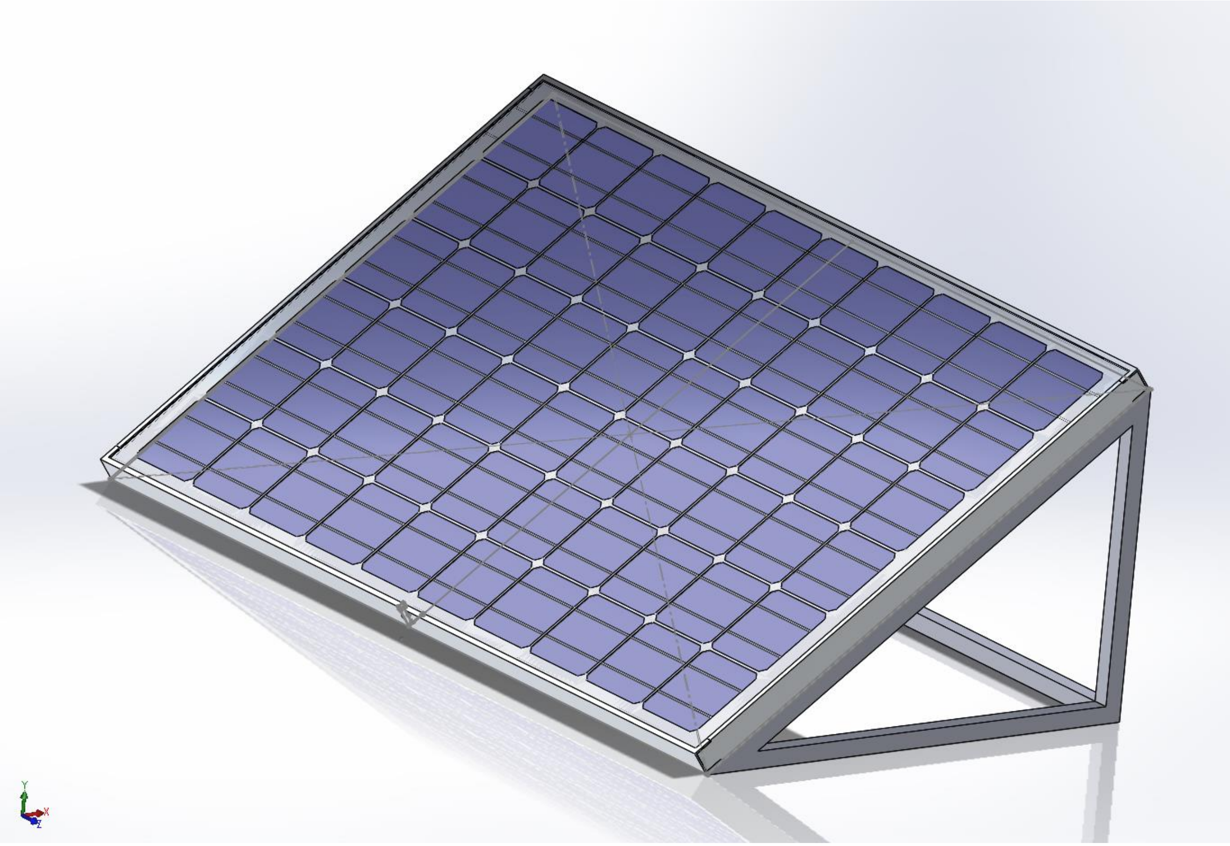
Decision Matrix

Decision matrix for the display options

Decision Criteria	Decision Criteria Weights	Pre-Programmed	Team Programmed	Tablet
Cost	0.05	3	4	3
Reliability	0.40	4	3	2
Customization	0.15	4	5	2
Man Hours	0.10	5	2	2
Adaptability	0.30	4	4	1
Total		4.05	3.55	1.75

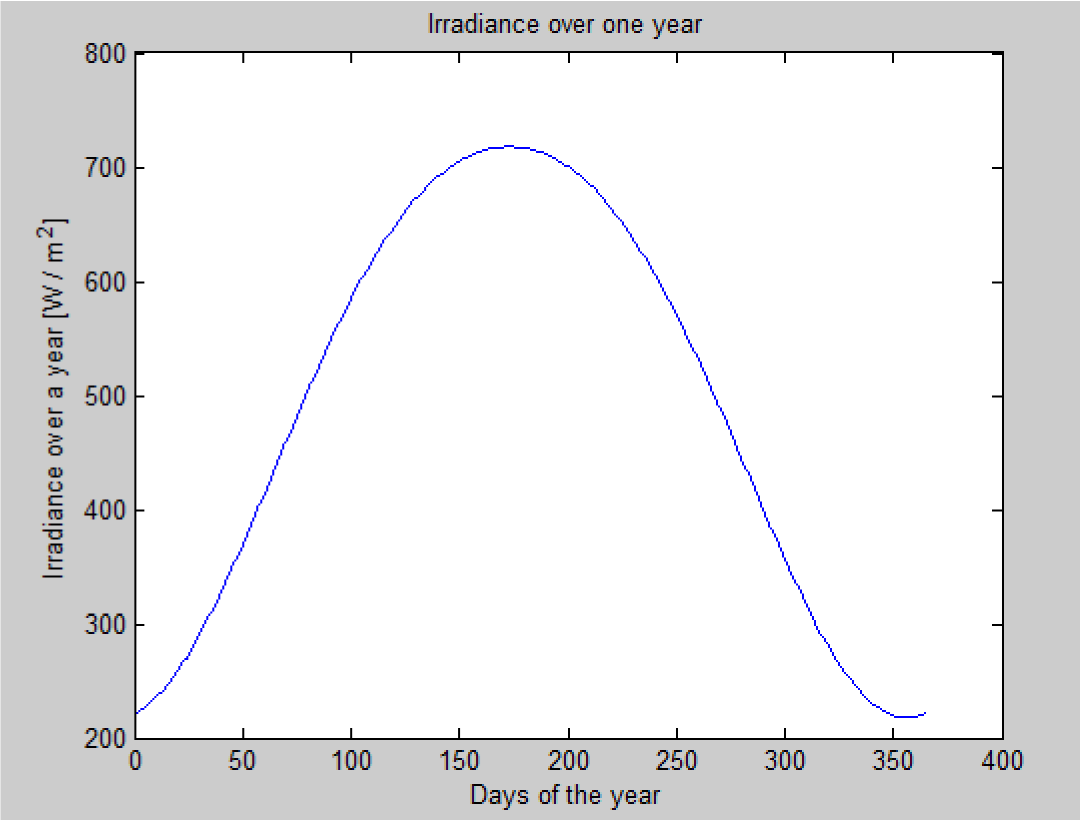
PV Panel

PV panel angled at 35°



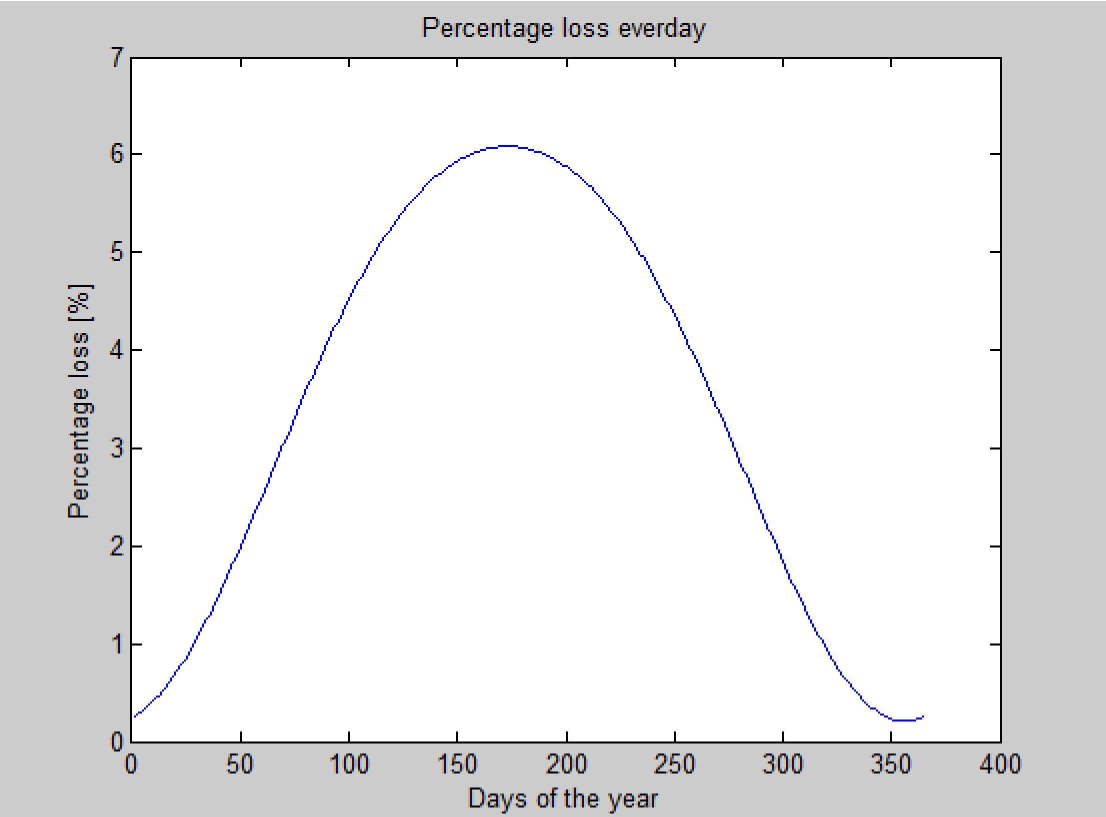
- 7 ASE-300-DG/50 panels
- PV panel are placed at 35° facing due south
- All of the engineering analysis followed are calculated based on this orientation

Irradiance



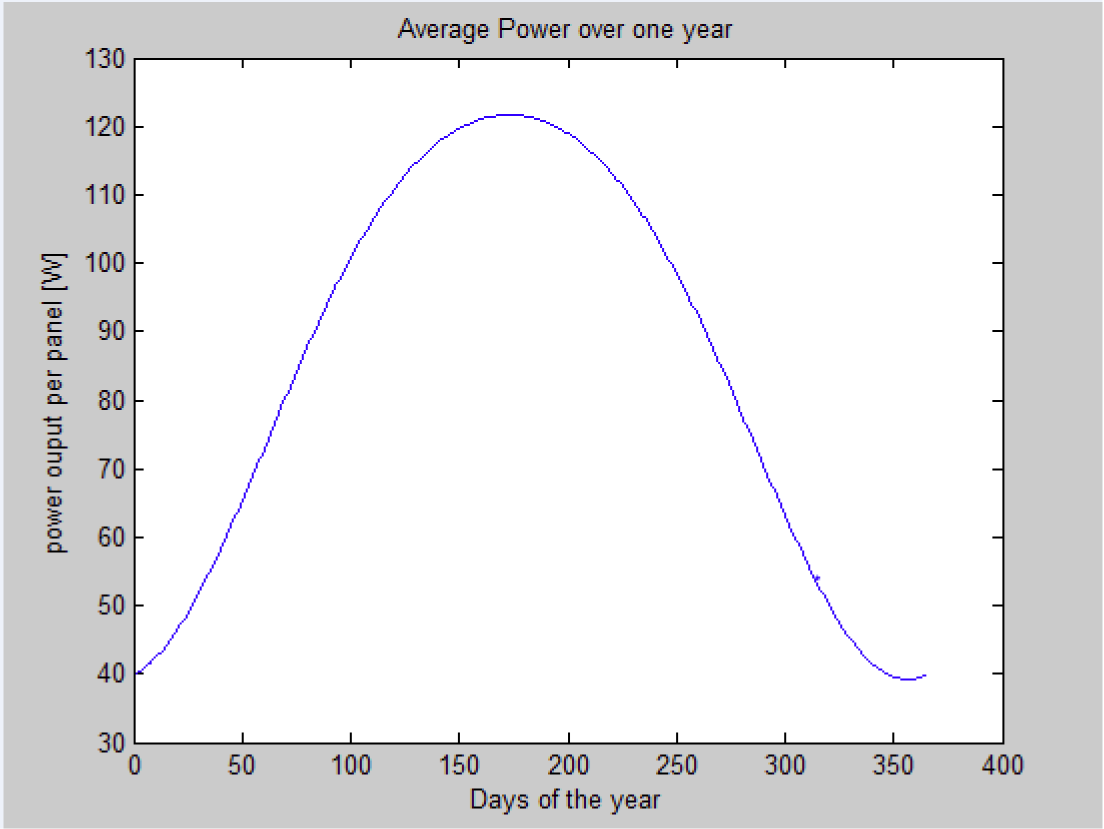
- The irradiance is based on the ideal irradiance of 1000W/m² ,the zenith angle, declination angle, hour angle and latitude of Flagstaff
- The zenith angle is the angle between the vertical and the line to the sun
- The declination angle is the angle between the equator and a line drawn from the center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

Percent Loss



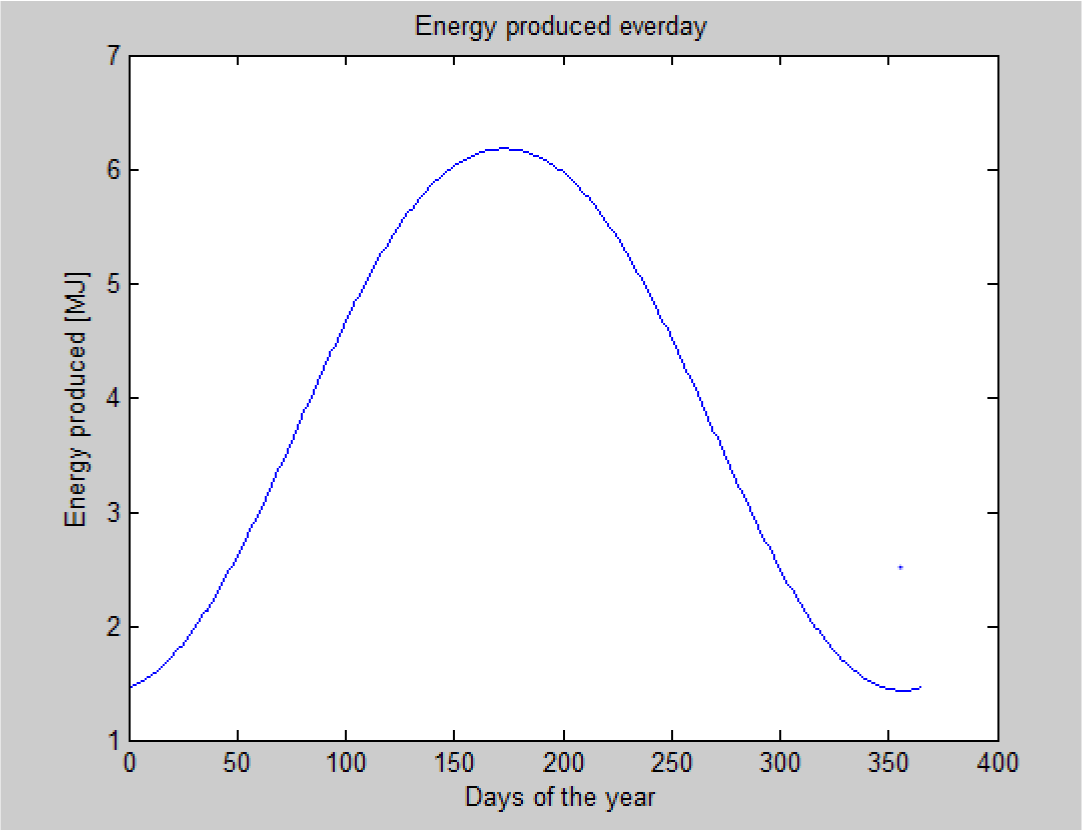
- Percent loss represents the energy loss due to high temperature
- The percent loss increases during the summer months because it gets hotter during that time due to a more prolonged exposure to sunlight
- $Tcell = Tair + \frac{NOCT - 25}{800}$ x Irradiance
- $Percent\ loss = (Tcell\ - 25)$ x TCoP
- NOCT is the nominal operating cell temperature
- TCoP is the temperature coefficient of power
- TCoP = 0.47 % per ºC

Power



- The power output is determined based off of the irradiance going into the PV panel, and the losses experienced by the panel
- P = Irradiance x 0.19 x (1 - percent loss) x (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
- $\frac{Watt-hours}{day} * days\ of\ autonomy * \frac{1}{depth\ of\ discharge} = total\ amount\ of\ watt - hours$
- 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
- $Amps_{req} = Power\ _{panels}/Voltage_{batteries}$

- $Amps_{req} = \frac{792\text{W}}{48\text{V}} = 16.5\text{A}$

- 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

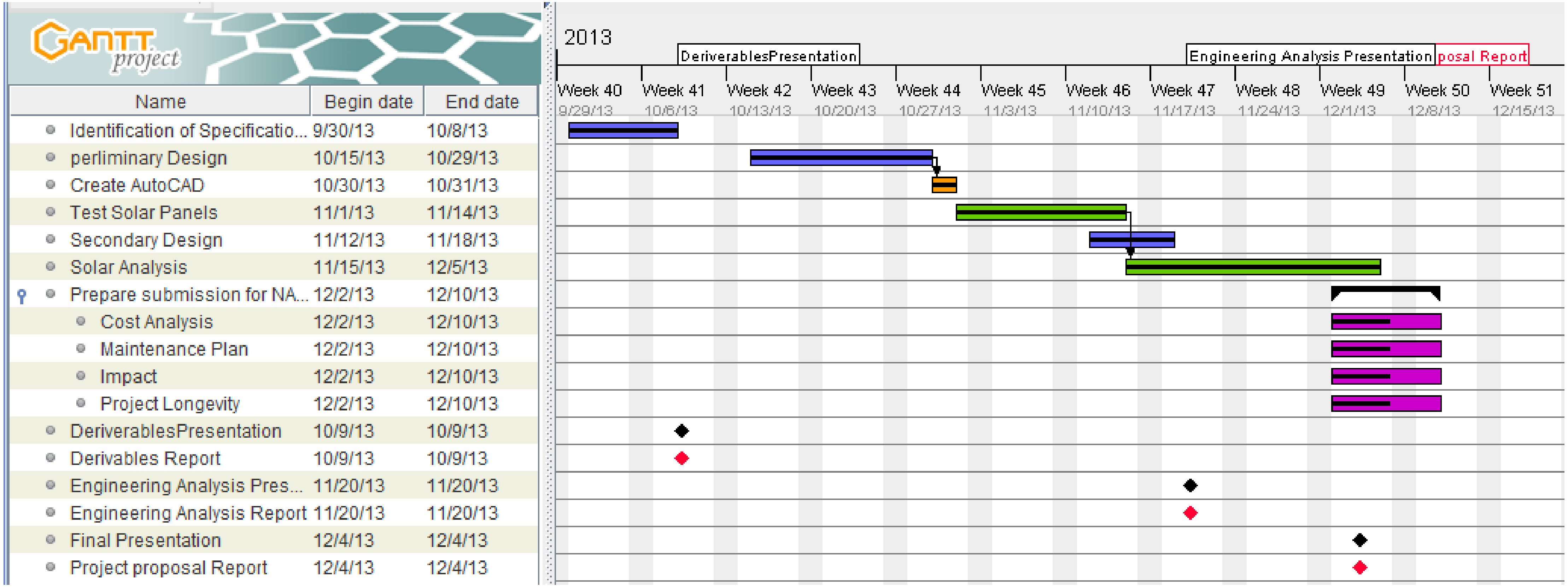
Budget

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

Tyler Faulkner

Gantt Chart

Project Progress



Name	Begin date	End date
Identification of Specificatio...	9/30/13	10/8/13
perliminary Design	10/15/13	10/29/13
Create AutoCAD	10/30/13	10/31/13
Test Solar Panels	11/1/13	11/14/13
Secondary Design	11/12/13	11/18/13
Solar Analysis	11/15/13	12/5/13
Prepare submission for NA...	12/2/13	12/10/13
Cost Analysis	12/2/13	12/10/13
Maintenance Plan	12/2/13	12/10/13
Impact	12/2/13	12/10/13
Project Longevity	12/2/13	12/10/13
DeriverablesPresentation	10/9/13	10/9/13
Derivables Report	10/9/13	10/9/13
Engineering Analysis Pres...	11/20/13	11/20/13
Engineering Analysis Report	11/20/13	11/20/13
Final Presentation	12/4/13	12/4/13
Project proposal Report	12/4/13	12/4/13

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

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Questions?