Sunny Side Up

EML 4501
Summer 2021

Abstract

Welcome to group 3's heliostat design - inspired by sustainability, efficiency, and simplicity. The design focuses on reducing complexity by eliminating unnecessary components and assemblies. The full heliostat assembly features a T-beam structure, a belt driven articulation system, and reflective surfaces consisting of highly reflective solar film adhered to two aluminum sheet metal panels for rigidity. The exhilarating field design calculated how to create a concentration factor of over 1,000 suns - generating enough power for the customer by placing over 2,000 heliostats in a radial cornfield layout. Despite being the smallest group, group 3 has been working non-stop to create the best heliostat design in hopes that the UF research department will want to manufacture our design. In the case that our design is selected for production, each member could profit off their intellectual property that went into generating the final product. We invite you to find answers to your engineering questions, figure out our inspiration for the design, and come find out what it really means to be an engineering with group 3.

Cost

OTS Parts	$71.97
Raw Materials	$22.50
Manufacturing	$13.64
Total	$108.11

Overview

Sunny Side Up is a dual-axis solar tracking heliostat designed to redirect sunlight to a central tower throughout the day. A solar concentration field of ~1700 of these modules is capable of producing 1.01MW.

Figure 1. Total Assembly of the Heliostat

Design Requirements

1. Total collection area of a single heliostat module is ≤ 1 m^2
2. Each module must be composed of 2-16 heliostats
3. Each module must mitigate optical losses due to tracking errors not to exceed 40%
4. Each module must be capable of tracking the sun throughout the day.
5. Individual heliostats within module units cannot shade other heliostats in that unit.
6. Modules must redirect sunlight to receiver target mounted on a central tower up to 100 m tall
7. Overall cost of an individual heliostat module must be below $100/m^2.
8. Sun tracking by individual heliostats should be automated and computer controlled
9. The total module area relative to the reflecting area should be small
10. Individual parts must be equal in price or less expensive than the closest available OTS part.
11. The reflecting surface of each heliostat must be washable using conventional cleaning techniques to remove dust and residue.
12. The solar energy collection field made of individual heliostat units must deliver to a central receiving tower target a concentrated focal thermal input power of 1 [MW] after losses.
13. The concentrating solar energy collection field must provide a solar concentration ratio greater than 1000 suns
14. The distance of heliostat units furthest from the collector target tower must account for dispersion of reflected light from the heliostats relative to the size of the absorbing aperture of the solar receiver target
15. Operational lifetime of the installation must exceed 20 years
16. The system operates under ambient and solar conditions in Las Vegas, NV (36 °Nin the American Southwest)
17. Adequate spacing must be provided for a conventional cleaning vehicle to pass through the arrangement of heliostat modules and access all units for cleaning
18. The topography of the overall installation may be assumed to be completely flat

Support

- The structure subassembly consists of a main support beam, cross support, and support swivel
- Main support will be driven into the ground and serves to hold the entire assembly
- Cross support will hold the reflective panels in place as they rotate on the elevation axis
- Support Swivel serves to hold the cross support in place as it rotates on the azimuth axis
- Using an Ashby plot, 6061-T6 aluminum was selected as the material for each component due to its economy, corrosion resilience, and strength
- A structural analysis was conducted to determine the safety rating due to extreme weather conditions (80 mph wind)
- Comparing the bending moment with the yield strength of 6061-T6 aluminum yields a factor of safety of 2.4

Articulation

- Responsible for the design's capability for dual-axis solar tracking
- Featuring NEMA 23 Stepper motors, computer controlled, with an enclosure rating of IP 55
- Belt and pully system used for accuracy in tracking
- Belt system increases lifetime and reduces overall cost
- A wind load analysis was conducted to determine the highest wind speeds at which the motors can operate
- It was determined that our motors can operate in 20 mph winds

Optics

- Two painted aluminum plates laminated with 3M's Solar Mirror Film 1100
- Reflectivity value of 0.94
- Designed to be lighter, cheaper, and more durable than the use of silvered-glass mirrors
- Most efficient Radial Staggered Layout chosen
- North field 45° in east and west directions (90° total)
- Only 1.6 meters spacing between modules in the same row
- 4.5 m spacing between rows to allow for vehicle transport
- 22,432 m^2 total field area with a maximum radial distance of 169 m.
- 1684 total modules producing 1.01 MW with an assumed 40% optical error in worst case scenario
- Receiver height at 100 m and receiver area facing field to be 1.66 m^2

Customer Need	Metric	Subsystem	Feature
C7: Overall cost below $100/m^2$	< $100/m^2$	***Structure***	F1 (C7): All components + manufacturing costs <$100/module
C9: Total module area small relative to mirror	< 1.20 module S.A/reflective S.A		F2 (C9): T-beam structure reduces module area (<1.2 m^2)
C10: Parts cheaper than OTS options	Individual parts cost ≤ OTS parts		F3 (C10): OTS components used wherever possible
C11: Washable using conventional methods	IP55 waterproof rating		F4 (C11): Aluminum and other corrosion resistant materials used
			F5 (C11): All electronics sealed from dust and moisture
C16: Operates in Las Vegas	Operate with avg. UV index of 5 and wind up to 80 mph		F6 (C16): UV resistant materials (aluminum, Delrin, and coated steel)
			F7 (C16): Structural factor of safety of 2.4 @ 80 mph
C4: Must be able to track the sun	< 0.5 deg tracking error	***Dynamics/Articulation***	F8 (C4): Microstepping motor driver with 0.05° resolution
			F9 (C4): Gear ratio of 1.7 from motor output to mirror movement
C6: Rceiver tower up to 100 m tall	≤ 2 m accuracy on tower up to 100 m tall		F10 (C6): 180° motion in both axes
C7: Overall cost below $100/m^2$	< $100/m^2$		F1 (C7): All components + manufacturing costs <$100/module
C8: Sun tracking should be automated	≥ level 3 autonomy		F11 (C8): Raspberry Pi microcontroller used to control movement
C10: Parts cheaper than OTS options	Individual parts cost ≤ OTS parts		F3 (C10): OTS components used wherever possible
C11: Washable using conventional methods	IP55 waterproof rating		F4 (C11): Aluminum and other corrosion resistant materials used
			F5 (C11): All electronics sealed from dust and moisture
			F12 (C11): IP66 water resistance rated NEMA 23 motors used
C15: 20 year life	≥ 20 year lifetime		F13 (C15): Long lasting neoprene belts used for drive mechanism
C16: Operates in Las Vegas	Operate with avg UV index of 5 and wind up to 80 mph		F14 (C16): UV/weather resistant neoprene belts increase life
			F15 (C16): NEMA 23 motor producing 2.8 Nm of torque
C1: Total collection area of ≤ 1 m^2	≤ 1 m^2 total module collection area	***Optics***	F16 (C1): Aluminum plates laminated with solar film equaling 1 m^2
C2: Each module must have 2-16 heliostats	2-16 heliostats per module		F17 (C2): Two heliostats contained within the module
C3: Optical loss less than 40% @ 0.5° tracking error	< 40% loss due to tracking errors		F18 (C3): Tracking error quantified in terms of accuracy, receiver size determined to minimize optical losses
C5: Cannot shade other heliostats	< 1% of reflective area shaded		F19 (C5): Intramodular heliostats are coplanar
C7: Overall cost below $100/m^2$	≤ 1 m accuracy on tower up to 100 m tall		F20 (C7): Solar film selected to be inexpensive compared to mirror based models.
C10: Parts cheaper than OTS options	Individual parts cost ≤ OTS parts		F21 (C10): Laminated aluminum mirrors cheaper than mirror alternatives
C11: Washable using conventional methods	IP55 waterproof rating		F22 (C11): Films are washable
C12: Thermal input power of 1 MW to receiver	1 MW solar power after losses		F23 (C12): Total module calculations made to reach 1 MW, including 40% optical error
C13: Concentration ratio greater than 1000 suns	$A_{reflector}/A_{receiver} > 1000$		F24 (C13): 1684 m^2 reflective area to 1.66 m^2 receiver area
C14: Maximum distance must account for dispersion	≤ 100 m radial distance form receiver		F25 (C14): Atmospheric Attenuation has minimal effect under 1000m, radial distance increased with justification
C15: 20 year life	≥ 20 year lifetime		F26 (C15): Reflectivity of film does not degrade significantly with time, recaulking can be done to prevent film peeling
C17: Spacing for conventional cleaning vehicle	≥ 4 m spacing between rows of modules		F27 (C17): 4.5 m spacing between rows