QuadFlector

Moving Energy 4ward

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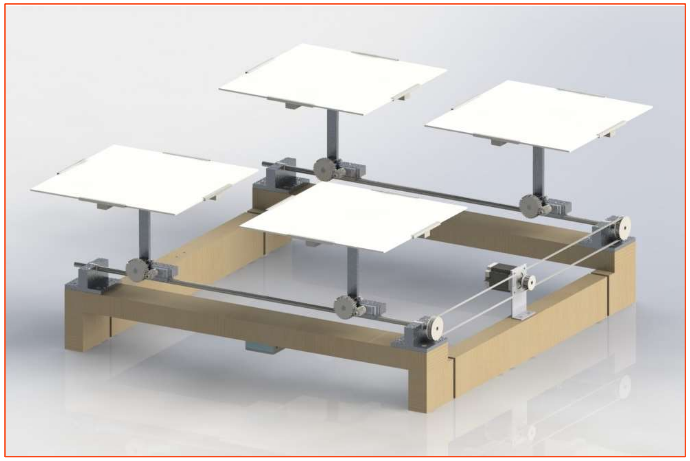
Abstract

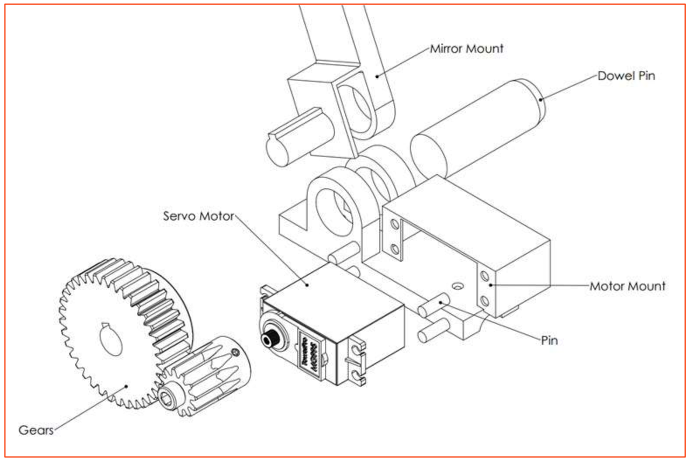
The QuadFlector is a modular reflector with four heliostats, each with an individual axis of rotation (roll) and all unified in motion in one tandem axis of rotation (pitch). Throughout the design of the QuadFlector, the preservation of ease of assembly and maintenance was determined to be paramount in the distinction of the QuadFlector from other competing designs. To achieve this, an open face design was implemented: allowing an operator direct access to each of the main components. Through use of a mirror mount, expired reflectors can be replaced rapidly. The placement of the drive belt enables easy installation and replacement without complicated disassembly of other system components. The appropriately weather resistant components are mounted in such a way that accumulation of rainwater and dust particles is not impactful to the continued operation of the module. To achieve the desired accuracy (0.8°), the selected stepper motor driver provides a resolution of 0.1125° to the pitch of the reflectors, and the servo motors chosen (with the selected gear ratio) provide a resolution of 0.6° in the roll direction of the reflectors: combining to a total positional error of 0.61°. The open-source software used to determine optimal positioning of each heliostat, based on the provided solar tracking data, delivers an optimized thermal output per module. To reach the desired solar concentration on the central tower, a field of 1,067 QuadFlector modules is required.

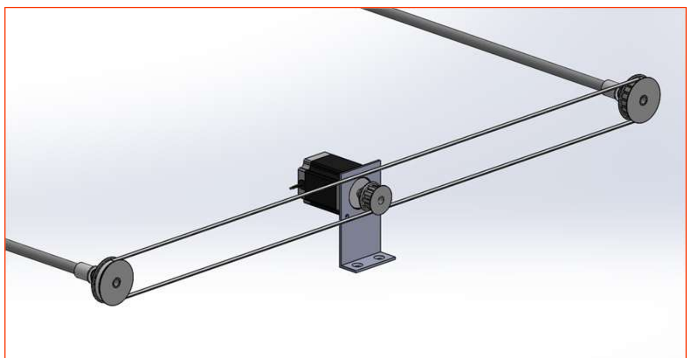
Description of Operation

The QuadFlector is a heliostat module designed to operate in a concentrated solar power plant near Las Vegas, Nevada. Each module contains 0.64 m^2 of reflective material mounted onto a compact frame. Each QuadFlector receives a wireless signal from a centralized communication unit which controls where the modules reflectors point towards. The full solar field of reflectors will redirect sunlight onto the receiver, delivering the desired heat for a 1 MW methane reforming reactor.

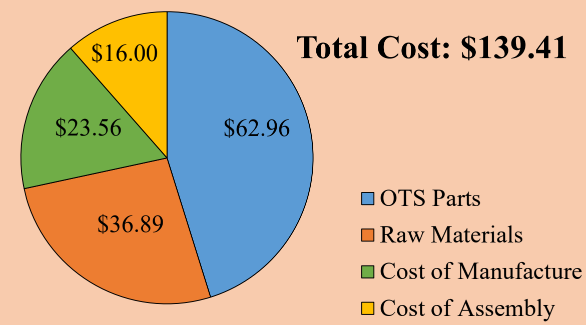
The simplicity of the design enables relatively unskilled laborers to perform assembly. By maintaining an open-face design, components can be easily interchanged once expired: decreasing long-term maintenance costs.







Approximate Cost per Single Module



Actuation Systems

A total of five motors are used per module. Each motor is connected to a central Arduino Uno controller: enabling easy conversion of existing open-source software.

Mirror Actuation

- Each heliostat is driven by a 3:1 gear train.
- Actuation is performed by a hobby servo motor, which provides a resolution of 0.60° to the roll.
- The rated motor torque for the utilized motors enables a maximum operating wind speed of 18mph.
- While maintaining a stationary position, the system can withstand wind speeds of up to 38mph.

Crossbar Actuation

- All heliostat mirrors are driven by a single stepper motor and connected via a belt.
- The stepper is mounted directly to the wood frame.
- Two mirrors are mounted on each of the two rods, and the angle of reflection for the pitch is uniform between all heliostats.
- The resolution of the stepper motor is 1.8° and a motor driver is used decrease the resolution to 0.1125° allowing the motor to directly drive the belt with no gearing: for a combined tracking error of 0.61°

Actuation	
Customer Need	**Quantified Factor**
4. Optical Losses from Tracking Error	Optical Losses, %
5. Tracking Sun Throughout Day	Average trackable time per day (hours) based on range of motion (degrees)
8. Cost must be <$100/m^2	Cost per heliostat actuation unit ($)
9. Automated and computer controlled sun tracking	Man hours per year requited to operate and maintain unit (hours)
11. Individual part cost vs closest available OTS part cost	(cost of all non-OTS parts) / (cost of all non-OTS parts' OTS equivalent part)
13. Factor of Safety to exceed N = 2	Lowest safety factor of actuation
14. Axes Inependent of Other Units	Number of independent axes
15. Lifetime to exceed 20 years	# of years actuation components can withstand based on # of cycles
16. Operates under ambient and solar conditions in Las Vegas, NV	Strength of wind necessary to affect funcitonality
	IP Rating
	Maximum Operating Temperature
	Total area of openings in housing susceptible to pests, dust, sand, etc.

Mirror	
Customer Need	**Quantified Factor**
2. Total reflector area <= 1 m^2	Percent of 1m^2 that the mirror's area occupies
7. Target mounted up to 100m tall must be reached	Rate per Unit Area Increase of Blocking
8. Cost must be <$100/m^2	Cost per heliostat mirror ($)
11. Individual part cost vs closest available OTS part cost	(cost of all non-OTS parts) / (cost of all non-OTS parts' OTS equivalent part)
12. Reflecting surface to be washable	# of cleaning chemicals that will not react with mirror material out of 5 common chemicals
16. Operates under ambient and solar conditions in Las Vegas, NV	Ultimate Strength of Material
	Hardness of Material
17. Thermal input >= 1MW for >= 1 hour/day	Emissivity of Heliostat Material
18. Solar concentraion > 1000 suns during operation time	Solar Concentration Ratio, (Area of Aperture/Area of Receiver)
19. Distance from heliostats to tower accounts for light dispersion	Maximum distance from tower still achieving required thermal input

Module	
Customer Need	**Quantified Factor**
1. Design capitilizes on small heliostat size	Total volume of module frame
3. 4-16 heliostats per module	Largest number of heliostats module can sufficiently hold
6. No shading during operating hours	Shadow length cast by module
8. Cost must be <$100/m^2	Cost per module ($)
9. Automated and computer controlled sun tracking	Area of module usable for attachment of actuation components
10. Total module area to reflective area to be small	Module Area/Reflective Area
11. Individual part cost vs closest available OTS part cost	(cost of all non-OTS parts) / (cost of all non-OTS parts' OTS equivalent part)
13. Factor of Safety to exceed N = 2	Number of Support Beams per Heliostat
15. Lifetime to exceed 20 years	# of years mirror can withstand based on # of cycles and weather conditions
16. Operates under ambient and solar conditions in Las Vegas, NV	Maximum wind velocity necessary to affect funcitonality