Heliostat Control Tracking

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CONCEPT OF OPERATIONS

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Concept of Operations
for
Heliostat Control Tracking

Team <66>

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Change Record

Rev.	Date	Originator	Approvals	Description
A	9/9/2022	Erica Quist, Samuel Dixon, Jordan George		Draft Release
B	9/30/2022	Erica Quist, Samuel Dixion, Jordan George		Updated System Description to accurately display new subsystem division. Updated block diagram to represent new systems. Updated Executive Statement.
C	10/13	Samuel Dixon		Removed highlighting, updated subsystems, and fixed grammar issues based on feedback.
D	11/16	Samuel Dixon		Updated project changes, repartitioning of subsystems

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1. Executive Summary

The goal of this research project is to help develop a heliostat for a small-scale solar thermal system consisting of a heliostat to Fresnel lens to target optical path. Currently, heliostat manufacturers design their products for very large CSP systems (concentrating solar power, i.e. power towers) that are not suitable for this R&D project as it would be too cumbersome, costly, possible proprietary issues, and the timeline would be unpredictable.

To demonstrate basic system performance in a timely manner, we will assemble a heliostat and demonstrate solar tracking, through a lens, to a focused target spot with motor control for two axis positioning of the heliostat into a fixed lens/target fixture and incorporate position feedback for closed loop operation. Having a stand-alone heliostat unit that can be easily setup, measured under sun, and returned to the lab for storage is desired. A small battery and possibly a PV panel and controller should be integrated onto the heliostat unit. Wireless control, sensor feedback, possibly a camera on the target area, data acquisition and data logging are desirable using a laptop (MS Windows) and Matlab. The solar input should be measured and an estimate of the solar energy delivered to the target area made (more on this later, we have to measure the direct normal irradiance - ie. DNI - separate from the global horizontal irradiance using a homemade rotating shadowband on an Apogee pyranometer).

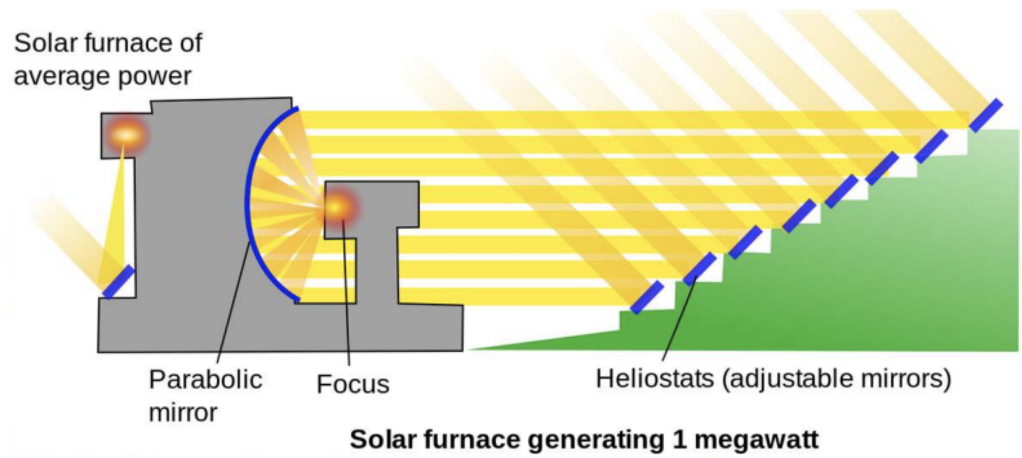

Figure 1: General concept of a solar furnace

2. Introduction

This paper provides an introduction to a Solar Tracking Mount for a solar furnace. This tracking mount will rotate and tilt the planar mirrors based on where the sun is located. The purpose of this would be to allow for the mirrors to concentrate more of the sun's energy onto the focal point of the solar furnace. A more efficient solar furnace would allow for the varying equipment that are powered by these devices to have a stronger source of power.

2.1. Background

The project will improve energy infrastructure and generation systems around the world by focusing light onto a target from the sun. Making use of the sun's available energy limits the dependence on non-renewable energies, which are currently being depleted at an unsustainable rate. Additionally, this sustains less environmental impact. This project seeks to improve the feedback control aspect for tracking the sun's position. This will be done by providing the control based on permutations of a multitude of parameters. Additionally, the method of connecting the mirrors and the motors to a provided frame for optimal optical alignment will be improved. This will be done through the use of hardware fasteners, actuators, and motors. This new configuration will provide optimal support for collecting the maximum amount of thermal energy on the target, while using minimal amounts of input power.

2.2. Overview

The Solar Tracking Mount will be started off by assembling the array of planar mirrors onto a single frame. The frame will have the ability to rotate and tilt the mirrors. Each mirror will have a motor to allow each mirror to have its own tilt. Also, there will be actuators that will be assisting the motors in the mission to tilt the mirrors in the optimal position. There will be sensors that will detect the optical output and input for each mirror. That data will be used to adjust the mirror until the maximum optical output is obtained. A sun tracking algorithm will be coded into the microprocessor to keep the mirrors in the most optimal position to output the most of the sun's energy. There will also be data visualization that the user of this tracking mount will be able to view. This will provide insight to the user of what exactly is happening with the mirrors and their optics information.

2.3. Referenced Documents and Standards

- https://www-sciencedirect-com.srv-proxy1.library.tamu.edu/science/article/pii/S0960148116311624
- http://www.powerfromthesun.net/Book/chapter08/chapter08.html
- https://www-sciencedirect-com.srv-proxy1.library.tamu.edu/science/article/pii/S0038092X00001560
- https://www.sunearthtools.com/dp/tools/pos_sun.php?lang=en#annual

3. Operating Concept

3.1. Scope

The Solar Tracking Mount will accelerate the transition to renewable energy by adaptively focusing the sun's light onto a target through the use of a rotating mirror array, commonly referred to as a heliostat. The target will be equipped with a sensor used to provide feedback into the processor of the motor drivers, actuating the adjustment of mirrors to an optimal point for maximized thermal output. The system will provide a data visualization device to communicate system-level information, such as sensors, current mode of operation, and log criteria observed for decision making.

3.2. Operational Description and Constraints

This project will be used in thermal energy conversion applications, particularly involving a thermal plate or furnace, in which heat is converted into another form of energy. Particularly, this system will serve as an input to a larger system, where electrical energy can be provided to consumers through renewable energy.

3.3. System Description

The Solar Mount Tracking will consist of controlling the motors that can rotate and tilt the mirrors, measuring the optical output and input of the mirrors, and an algorithm to allow the array of mirrors to track the sun and rotate accordingly. There are 6 subsystems for this project:

- PCB design
  - The PCB board will interface the tracking controls processor with the power supply, motors, data visualization tool, and sensors. The board is a place where the electrical components are organized and the signals are routed to their respective positions.The board also handles the power distribution and delivery to all the various components.
- Data visualization
  - This tool will provide valuable insight to verify different aspects of the system and communicate different metrics across the system to the user.
- Tracking Controls
  - The tracking controls are the processor and brain of the system. Through feedback received from the sensors, time of day, and other sources of valuable information, will decide how to change the positioning of the mirrors in the system.
- Optical Mirror Setup
  - The physical setup is how the motors, mirrors, actuators, and frame will be configured. By creating a controllable array of mirrors on a frame, the controller's job will be easier to effectively channel the light onto the target. Although

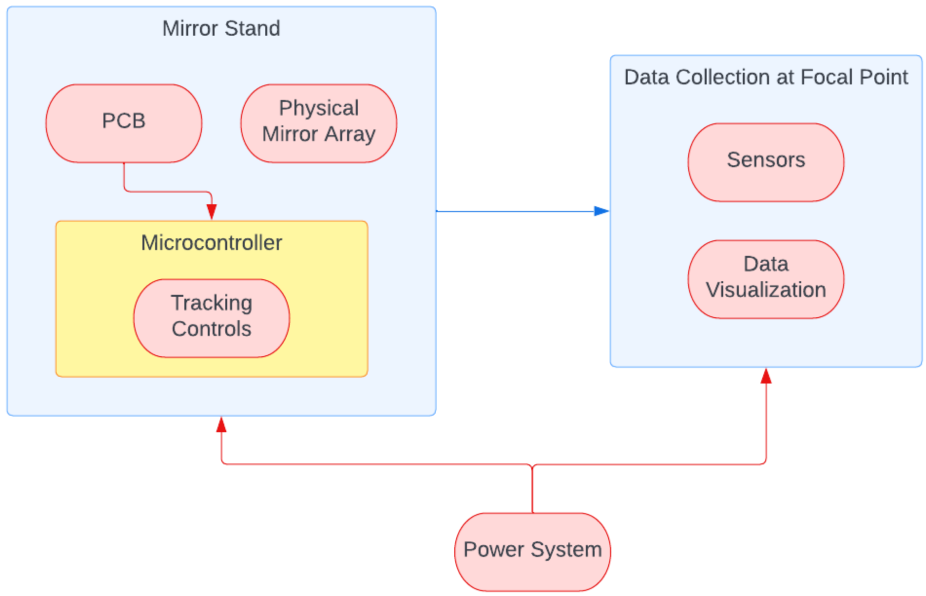

Figure 2: Subsystem block diagram

3.4. Modes of Operations

The system will have different modes of operations depending on the time, weather, and season. Specifically, the system will have four modes: a sleep mode (for times when it is impractical to have the system, such as night), full range operating (for times when the sun is fully available), partial range operating (for seasons, such as winter, or weather, such as cloudy for when the optimum amount of sunlight is not available), and lastly, the system will have a debug mode (where the system is expecting to be tested, changed, and manipulated).

3.5. Users

Researchers, utility providers, and customers are all potential users of this system. This system intends to be a basis for providing sustainable energy for use. By providing robust tracking of the movements in the sun, change in weather, and different seasons, the system gives researchers a head start in thermal energy conversion systems, where heat can be converted into a more useful form, such as electricity. This would provide utility providers a method of incorporating a renewable energy source to distribute power to different businesses.

3.6. Support

Support will be provided through a user manual. The document will describe the scope of the system, the purpose, and how to change operating modes and parameters in the program. Additionally, the manual will provide information on how to “power on” the system and use the Android application for data interpretation.

4. Scenario(s)

4.1. Campsite bathroom lighting

When camping there is commonly a public bathroom available for people to use. Sometimes these public bathrooms are transportable and have no electrical power, but other times they are established bathrooms with lighting. A potential use case of this application would be to replace the energy source of the bathrooms with lighting. Fortunately, when camping there is typical natural light during the day. Using this application to collect and store energy during the day, when natural light is available in the bathroom would let non-renewable energy be replaced in the evening, when lighting is needed.

4.2. Airport Charging Applications

When traveling there is a varying demand of people needing to charge appliances in airports. This variation is due to the nature of supply and demand. Increased travel typically occurs when people have an abundance of time, cultural holidays, and the price of tickets. In airports, there is a large amount of variation in power required to charge electrical appliances, such as phones or laptops. In a smaller airport near the tropical, sunny climate, these spikes of variation could be accounted for by this problem.

4.3. Thermal Energy System Research

There is substantial research being done in thermal energy conversion systems. This system would provide a valuable input into those systems, as the optimal supply would be provided to enable the largest throughput possible for usable energy at the output of their energy conversion system.

5. Analysis

5.1. Summary of Proposed Improvements

This system will provide improvements in tracking, by basing the feedback on a diverse suite of parameters. Additionally, the proposed system will provide data driven-insights based on the light collected on the target and the positioning of the motors. Lastly, the system will offer in-program functionality adjustments and calibration to accommodate different geographic locations and conditions.

5.2. Disadvantages and Limitations

The proposed system will have some apparent limitations. Quite notably, is the fluctuation in the ability to focus light during inclement weather, different seasons, and the time of day. Additionally, there may be substantial tradeoffs in the power needed to power the system and the amount of light focussed on the target.

5.3. Alternatives

An alternative solution may be to use solar panels rather than mirrors when tracking the light, although this alternative could potentially be more costly to implement for collecting the sun’s energy. Additionally, maintenance for mirror damage is likely less expensive than the cost of damage incurred on a solar panel. Another alternative could be to control the thermal plate to collect the energy, rather than focus the light through mirrors. This method would reduce the complexity of having both a target and a focussing system, although without focussing the light, a reduction in luminous intensity would be observed. The tradeoff here is observed between complexity and energy collected. Additionally, there would be less spatial coverage, as heat dissipates with a larger surface area.

5.4. Impact

The project impacts the way society uses energy. Currently, the majority of the world’s energy consumption is derived from fossil fuels. Recent trends and investments show that the world is on track to change the majority of reliance to more sustainable alternatives. Through applications like this the world can accelerate the push to sustain the shift to a different form of energy. The implications of this shift would be an increase in the availability of fossil fuel supply, an alleviation of environmental stress and pollution ,a transformation of job markets in certain industries, and a shift in the marketplace value of certain commodities and businesses.