Harnessing the Sun:
A Proposal for Advanced Heliostat Implementation to device Concentrated Solar Power in Bangladesh

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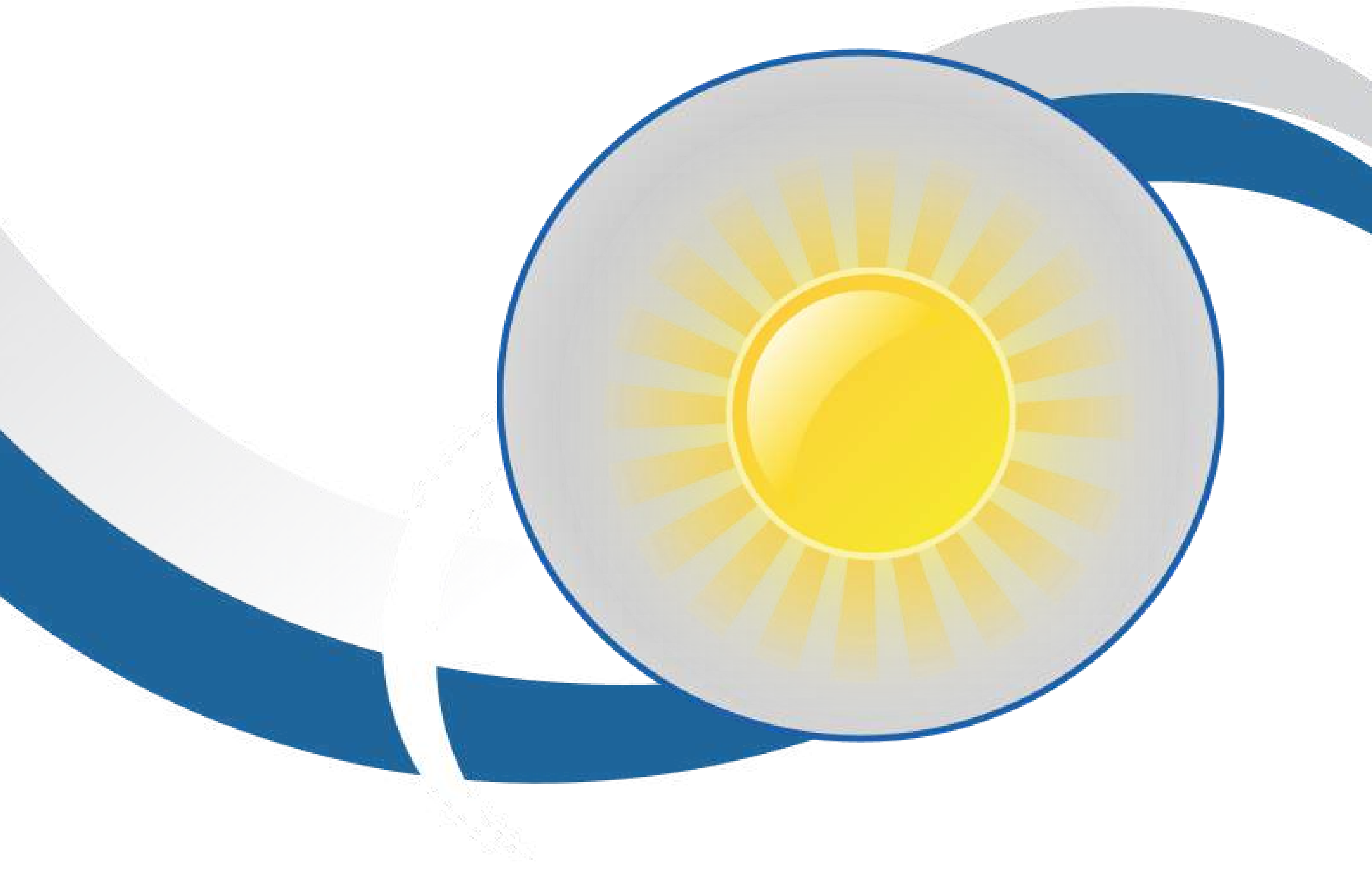

Contents

Executive Summary

The proposed project aims to address the ongoing power crisis in Bangladesh by leveraging the country's abundant solar radiation and favorable geographical conditions. The implementation of Concentrated Solar Power (CSP) using robustly designed heliostats could significantly contribute to the nation's energy objectives. This aligns with Bangladesh's goals of increasing the use of renewable energy and reducing carbon emissions.

The project's deliverables include a comprehensive feasibility study, a robust heliostat design, and a detailed implementation plan. The design considerations for the heliostats take into account the country's susceptibility to natural disasters, ensuring the sustainability and reliability of the project.

The project requires advanced design and simulation software, project management tools, a well-equipped manufacturing facility, a testing facility, and a suitable deployment site in Bangladesh. The project timeline spans from design to deployment, with each phase expected to take several months.

In essence, this project represents a significant step towards a sustainable and reliable power supply in Bangladesh, thereby reducing the country's reliance on fossil fuels and diesel-powered power facilities. It also contributes to the global effort to mitigate climate change by promoting the use of renewable energy sources. This project is not only a solution to the current power crisis but also a step towards a greener and more sustainable future for Bangladesh. We believe that with the right resources and commitment, this project can be successfully implemented to benefit the people of Bangladesh and the environment.

Project Background

Current Power Generation Crisis in Bangladesh

Bangladesh is currently dealing with a serious problem with its electricity supply. Bangladesh is not an exception to the fact that the globe is currently experiencing one of the biggest energy crises in history. A number of things have contributed to the issue, such as the Covid epidemic, the conflict between Russia and Ukraine, and the ensuing spike in food and energy costs.

In October 2022, a problem with the nation's electricity grid caused blackouts to occur in 75–80% of the country. This came about as a result of the government's decision to halt operations at all diesel-powered power facilities in order to lower import costs due to the sharp increase in prices. The shutdown of these diesel-powered power facilities reduced output by up to 1500 megawatts, accounting for around 6% of Bangladesh's total power generation.

Necessity of Renewable Energy in Bangladesh

The necessity of implementing sustainable and renewable energy to lessen the climate impact of fossil fuels has been highlighted by the present global energy crisis. This is especially crucial for Bangladesh, a nation that is among the most climate-vulnerable despite producing less than 1% of the world's carbon emissions.

Bangladesh has set aggressive targets to cut carbon emissions by 21.8 percent by 2030, with a particular emphasis on energy efficiency and increased usage of renewable energy. Bangladesh has set a goal of producing 40% of its energy from renewable sources by 2041 as part of its transition to renewable energy.

Concentrating Solar Power (CSP) in Bangladesh

A possible method of generating electricity is called concentrated solar power (CSP), which involves concentrating sun radiation to create a high temperature needed to produce steam in a solar thermal power plant. This technique produces no greenhouse gasses because it doesn't require fossil fuels.

A CSP plant can be operated in Bangladesh with an average yearly Direct Normal Irradiance (DNI) of over 1,900 kWh/m2. Since CSP doesn't require fuel, it might be a desirable option to lessen Bangladesh's power crisis.

Limitations of CSP

The main device to be used to concentrate solar power is Heliostat. Heliostats are hexagonal, concave mirrors designed to focus sunlight onto a single point. This focal point is a tower equipped to absorb the heat. The tower contains water which, when heated, vaporizes and drives a steam turbine to generate electricity.

CSP is a newer technology in the power generation sector and the heliostat is not fully optimized for deployment in a disaster prone country like Bangladesh. The most suitable site for implementation of a CSP plant is near the coastal region, because CSP will be the power source and we are going to need lots of water to generate electricity. But the coastal region of Bangladesh presents few challenges-

1. Tracking the sun to increase the efficiency of the heliostat, and
2. Providing a fluid and aerodynamic design to withstand natural disaster

In this paper, we will be trying to solve the first problem, i.e., tracking the sun precisely and adjusting the heliostats accordingly.

Solution

Bangladesh, with its abundant solar radiation and favorable geographical conditions, presents a unique opportunity for harnessing solar energy. The deployment of heliostats—mirrors that automatically track the sun—can significantly contribute to the nation's energy objectives. However, to optimize their efficiency, we must address several key aspects.

Heliostat Tracking Mechanism

Heliostats need to accurately track the sun's movement throughout the day. This ensures that they continuously reflect sunlight toward a central point where it can be utilized for power generation.

To achieve precise tracking, we propose using Light Dependent Resistors (LDRs). These sensors detect changes in ambient light and provide feedback to adjust the heliostat angles accordingly.

LDRs allow the heliostats to dynamically adapt to changing environmental conditions, such as cloud cover or variations in solar intensity.

Degrees of Freedom (DOF) for Heliostats

Our heliostats will be designed with three Degrees of Freedom (DOF). These refer to the different ways in which the mirrors can move:

Azimuth rotation (horizontal movement): The heliostats can rotate horizontally to follow the sun's east-to-west trajectory.

Elevation tilt (vertical movement): Adjusting the tilt angle allows the mirrors to capture sunlight optimally at different times of day.

Rotation around the mirror axis: Fine-tuning the mirror orientation ensures precise reflection.

The combination of these DOFs enables efficient sunlight capture throughout the day.

Tension Cable and Servo Motors

To achieve smooth movement, we'll connect each heliostat to a tension cable system.

Servo motors will drive the movement of the heliostats. These motors offer high precision and responsiveness, allowing us to adjust mirror angles accurately.

Notably, it is better using low-temperature servo motors capable of reliable operation even in extreme cold environments (as low as –40°C). These motors are essential for maintaining performance during harsh weather conditions.

By implementing LDRs, designing heliostats with 3 DOF, and utilizing tension cables with reliable servo motors, we can enhance solar energy capture in Bangladesh. This technology aligns with the nation's energy goals and contributes to sustainable development.

Overall Tracking Mechanism

A high precision tracking system that adopts the coordinate calculation algorithm and a photosensitive sensor. This system is designed to satisfy the precision requirement in sun tracking for a concentrated sunlight transmitting system via optical fibers. This system is based on a two-stage tracking process, which consists of a coarse adjustment based on the coordinate calculation algorithm and a fine adjustment using Light Dependent Resistors (LDR) placed along the edges of the hexagonal heliostat. By comparing the resistance, the direction of the sun will be determined where the intensity will be the highest. A predictive control process based on the running trend of sun traces will begin once the fine adjustment is completed.

In addition, all the heliostats will be interconnected through a centralized control system to ensure optimal performance and synchronization. The reflected sunlight from all the heliostats will be directed towards a specific point on a tower, known as the receiver. This receiver will be designed to adjust its height dynamically based on the focal point of the reflected sunlight. To achieve this precise height adjustment, a Stepper Motor will be used due to its high accuracy and control in positioning and speed. This integration of heliostats and the receiver tower will further enhance the efficiency of solar energy capture.

Deliverables and Goals

Project Deliverables

1. Solar Tracking Mechanism: A system using Light Dependent Resistors (LDRs) to accurately track the sun's movement throughout the day, ensuring that heliostats continuously reflect sunlight toward a central point for power generation. Moreover, Heliostats will be designed with three Degrees of Freedom (DOF) - azimuth rotation (horizontal movement), elevation tilt (vertical movement), and rotation around the mirror axis. This design enables efficient sunlight capture throughout the day. Besides, a tension cable system connected to each heliostat to achieve smooth movement. The use of low-temperature servo motors to drive the movement of the heliostats, offering high precision and responsiveness.
2. Centralized Control System: A system to interconnect all the heliostats, ensuring optimal performance and synchronization.

3. Dynamic Receiver Tower: A receiver tower designed to adjust its height dynamically based on the focal point of the reflected sunlight. A Stepper Motor will be used for this precise height adjustment.

Project Goals

1. Address Power Generation Crisis: To address the current power generation crisis in Bangladesh by harnessing solar energy through Concentrated Solar Power (CSP).
2. Promote Renewable Energy: To promote the use of renewable energy in line with Bangladesh's goal of producing 40% of its energy from renewable sources by 2041.
3. Optimize Heliostat Efficiency: To optimize the efficiency of heliostats by implementing a precise tracking mechanism, designing with 3 DOF, and utilizing tension cables with reliable servo motors.
4. Enhance Solar Energy Capture: To enhance solar energy capture in Bangladesh through the integration of heliostats and the receiver tower, contributing to the nation's energy goals and sustainable development.

The project will meet the demands of the current situation in Bangladesh. It addresses the power generation crisis by proposing a shift towards renewable energy, specifically CSP. The implementation of CSP using heliostats could significantly change the existing scenario by providing a sustainable and reliable power supply, thereby reducing the country's reliance on fossil fuels and diesel-powered power facilities. This aligns with Bangladesh's goals of increasing the use of renewable energy and reducing carbon emissions. The proposed design considerations for the heliostats also take into account the country's susceptibility to natural disasters, ensuring the sustainability and reliability of the project.

Requirements

Required Hardwares

1. Concave mirror, hexagonal shape, Focal Length: 8-10 m, Area: 0.325 m^2, side length: 0.5 m
2. Heliostat frame (Hexagonal Shaped)
3. Solar Tower (5 Meter)
4. LDR Sensors
5. Stepper Motor and Driver
6. Servo Motors
7. Tension Cable
8. Resistor
9. Microcontroller (Arduino for the prototype)

Facilities Needed

1. Testing Facility: After manufacturing the prototype, the heliostats need to be tested under simulated conditions to ensure their performance and durability. A testing facility equipped with the necessary equipment (heliostat and the tower) for these tests is required. A possible testing facility is the bank of the Padma.

2. Deployment Site: Upon the success of the project, a required amount of heliostats will be deployed for the generation of electricity. Possible sites for final deployment are: Bay of Bengal coastline, Kuakata, Sandwip, St. Martin.

Required Software

The project requires a sophisticated software system with the following functionalities:

1. **LDR Data Analysis**: The software should be capable of analyzing the resistance values from the Light Dependent Resistors (LDRs) installed on the heliostats. This data is crucial for determining the position of the sun.
2. **Sun Position Calculation**: The software should calculate the sun's location by comparing the resistance values along the edges of the hexagonal heliostats. This comparison will help in determining the direction where the sunlight intensity is the highest.
3. **Data Storage and Prediction**: The software should include a server for storing the collected data. This stored data will be used to predict the sun's location, ensuring a double-check mechanism to prevent miscalculations and misdirections of the heliostats.
4. **Heliostat Angle Monitoring**: The software should monitor the angle of each heliostat individually. This feature is essential to maintain synchronization among all the heliostats, ensuring that they all focus on a single spot.
5. **Integration with Hardware**: The software should be able to integrate seamlessly with the hardware components such as LDRs, servo motors, and the stepper motor. This integration is crucial for the dynamic adjustment of the heliostats and the receiver tower.
6. **User Interface**: A user-friendly interface for monitoring and controlling the system is also necessary. This interface should provide real-time data visualization and system status updates.

This software system will play a vital role in enhancing the efficiency of the Concentrated Solar Power (CSP) system, aligning with Bangladesh's energy goals and contributing to sustainable development. It will ensure precise tracking of the sun and optimal performance of the heliostats, thereby maximizing solar energy capture. The software will also contribute to the project's reliability and sustainability by preventing potential miscalculations and ensuring smooth operation of the system.

Project Timeline

1. **Manufacturing Phase:** The prototype manufacturing phase, which involves producing the heliostats based on the design, is expected to take between 15 to 20 days.
2. **Software Making Phase:** This is the longest phase and requires a lot of effort. The estimated time to construct the software is divided into different segments:
   A. LDR Data Analysis: This involves data analysis which might require around 2-3 weeks considering the complexity of the data and the analysis required.
   B. Sun Position Calculation: This is a complex calculation and might require around 2 weeks.
   C. Data Storage and Prediction: Setting up the server and implementing the prediction algorithm might take around 3-4 weeks.
   D. Heliostat Angle Monitoring: This feature might take around 2 weeks to implement.

E. Integration with Hardware: Depending on the complexity of the hardware, this might take around 3-4 weeks.
F. User Interface: Designing and implementing a user-friendly interface might take around 2-3 weeks.

   Considering these factors, for a team of 4, it might take around **14-18 weeks** to develop this software system.

3. **Testing Phase**: The testing phase, where the manufactured heliostats are tested under simulated conditions, is expected to take 5 days. This ensures that all heliostats meet the required performance and durability standards.

Conclusion

The proposed project aims to add a new dimension to the power generation sector of Bangladesh and presents a comprehensive plan to address the power generation crisis by harnessing solar energy through Concentrated Solar Power (CSP). The proposed solution involves the deployment of heliostats with a high precision tracking system, designed to maximize solar energy capture and contribute to the nation's renewable energy goals.

The project aligns with Bangladesh's commitment to reduce carbon emissions and increase the use of renewable energy. By implementing CSP using heliostats, we can provide a sustainable and reliable power supply, reducing the country's reliance on fossil fuels and diesel-powered power facilities.

The proposed solution requires the development of a sophisticated software system and the manufacturing of hardware components. The software will play a vital role in enhancing the efficiency of the CSP system, ensuring precise tracking of the sun and optimal performance of the heliostats. The hardware components, including the heliostats and the receiver tower, will be designed and manufactured to achieve maximum efficiency.

The project timeline estimates a total duration of approximately 18-23 weeks, including the manufacturing phase, software development phase, and testing phase. Upon successful completion of these phases, the project will move towards deployment, marking a significant step towards addressing the power generation crisis in Bangladesh and contributing to sustainable development.

In conclusion, this project represents a promising opportunity to harness solar energy in Bangladesh, offering a viable solution to the current power crisis and paving the way for a sustainable and resilient energy future.