Design and Implementation of Eco-Friendly Concentrated Solar Power (CSP)

Submitted in partial fulfillment of the
requirements for the degree
of

Bachelor of Science in Information and Communication Engineering

by

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APPROVAL

This is to certify that the entitled Design and Implementation of Eco-Friendly Concentrated Solar Power (CSP), submitted by First Author (Student ID: 201-50-013) and Second Author (Student ID: 201-50-008), and Third Author (Student ID: 201-50-009) are undergraduate students of the Department of ICE has been examined. Upon recommendation by the examination committee, we hereby accord our approval of it as the presented work and submitted report fulfills the requirements for its acceptance in partial fulfillment for the degree of Bachelor of Science in Information and Communication Engineering.

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We, First Author and Second Author, hereby declare that this capstone project titled "Design and Implementation of Eco-Friendly Concentrated Solar Power" is entirely our work, unless otherwise referenced or acknowledged. The content of this project is the result of our research and efforts, and we have complied with all ethical guidelines and academic standards.

We are aware of the consequences of academic dishonesty and understand that any violation of ethical standards in this project may lead to disciplinary actions as defined by Daffodil International University's policies.

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In conclusion, this project's success is a collective achievement made possible by the dedication, collaboration, and support of numerous individuals and organizations. We are profoundly grateful to everyone involved and look forward to continued collaboration and advancements in renewable energy technologies.

ABSTRACT

The goal of this project is to design and develop a concentrated solar power system that can generate a minimum of 10 W of electricity. Generally, a CSP system can generate heat at temperatures between 300°C and 1000°C (572°F and 1832°F), depending on the specific technology used. For example, parabolic trough systems, which are one of the most common types of CSP technology, can typically generate heat at temperatures between 300°C and 400°C (572°F and 752°F), while tower systems can generate heat at temperatures up to 1000°C (1832°F), which heats a fluid or material, such as molten salt or water. The steam can be used in cooking food. High-temperature heat generated by CSP can be used in various cooking applications, such as baking, roasting, and grilling. This can help reduce the amount of fossil fuels used in cooking and decrease carbon emissions. Also, it can be used to melt metals, extract minerals, or produce hydrogen gas. This can help reduce the carbon footprint of these processes by replacing fossil fuels with renewable energy. The system has been efficient, cost-effectives, and environmentally friendly. The project has aimed to improve the efficiency and performance of CSP technology and explore the potential for integrating CSP with other renewable energy sources such as wind and hydropower.

Keywords: CSP (concentrated solar power), Heat, Temperatures, Parabolic trough systems, Tower systems, Fluid, Molten salt, Fossil fuels, Carbon emissions, Environment friendly, Renewable energy sources, Hydropower Integration, Cooking Applications, Carbon, footprint.

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Chapter 1

INTRODUCTION

CSP, or Concentrated Solar Power, is a technology that harnesses sunlight to generate electricity. Unlike traditional photovoltaic (PV) systems that convert sunlight directly into electricity using semiconductor materials, CSP systems use mirrors or lenses to concentrate sunlight onto a small area.[1] This concentrated sunlight is then used to generate heat, which, in turn, drives a power-generating turbine.

Right now, the way we make energy is changing a lot. Instead of coal and oil, we're turning more to clean sources like solar and nuclear power. By the time we get to 2040, about 1/5 of all the energy we use might come from renewable sources like the sun and wind.
Solar energy, especially from the sun, is becoming super important. In 2013, the amount of solar energy we made jumped by 35%! In comparison, wind power increased by 12%, while geothermal and water power increased slightly. In figure 1.1 explains the different types of CSPs commonly use or implement in real life.

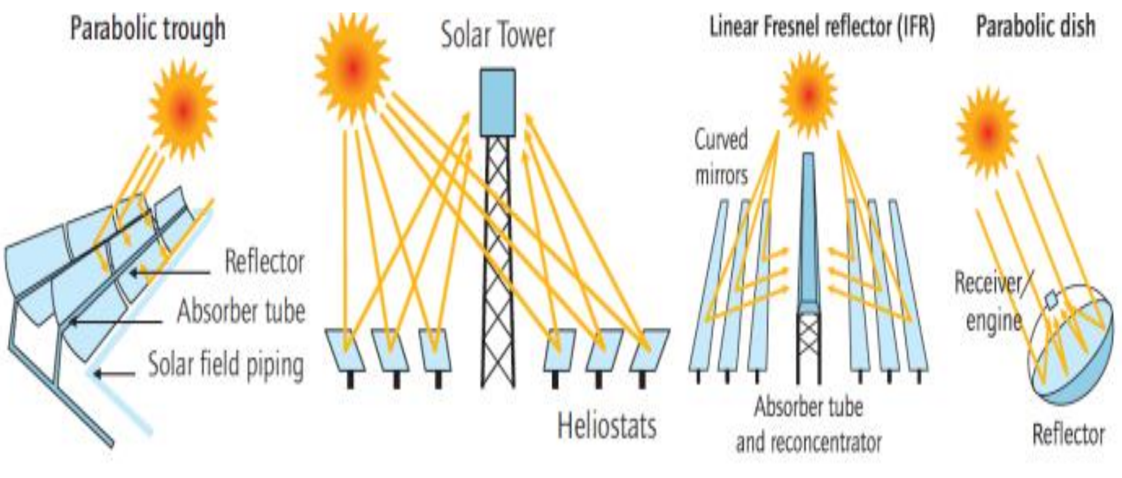

Figure 1.1: Types of CSP

1.1 Project Background

- **Literature Review:** Concentrated Solar Power (CSP) technology has emerged as a prominent renewable energy solution, utilizing solar radiation to produce electricity through various parabolic troughs and tower systems. Studies have highlighted the efficiency and scalability of CSP, emphasizing its potential to contribute significantly to sustainable energy production (Smith et al., 2020; Johnson & Patel, 2021). Additionally, research indicates the feasibility of integrating CSP with renewable sources like wind and hydropower to enhance energy production and reliability.

- **Relevance and Importance:** The urgency to address climate change and reduce carbon emissions underscores the relevance and importance of CSP technology. By harnessing solar energy, CSP offers a clean and sustainable alternative to fossil fuels, promoting environmental conservation and energy security. The proposed 10 MW CSP project aims to meet energy demands, reduce reliance on non-renewable resources, and contribute to global sustainability goals. Stakeholders, including energy providers, policymakers, and communities, stand to benefit from this innovative solution, driving economic growth and environmental stewardship.

- **Current State and Limitations:** While CSP technology has demonstrated considerable advancements, existing solutions encounter challenges such as high initial costs, land utilization requirements, and intermittency concerns. Moreover, integrating CSP with complementary renewable energy sources remains a developing area, necessitating further research and development to optimize system performance, storage capabilities, and cost-effectiveness.

- **Transition:** Given the existing literature, relevance, and limitations, this project seeks to design and develop a 10 MW CSP system that addresses current challenges and explores synergies with other renewable energy technologies. The subsequent sections will outline the project objectives, methodology, and anticipated outcomes, establishing a framework for advancing CSP technology and contributing to a sustainable energy landscape.

1.2 Project Definition

The primary objective of this project is to design, develop, and implement a 10 MW Concentrated Solar Power (CSP) system capable of harnessing solar energy efficiently, converting it into electricity, and integrating it with other renewable energy sources to sustain energy demands.

1.2.1 Problem Statement

The primary objective of this project is to design, develop, and implement a 10 MW Concentrated Solar Power (CSP) system capable of harnessing solar energy efficiently, converting it into electricity, and integrating it with other renewable energy sources to sustain energy demands.

1.2.2 Context and Scope

The scope encompasses technology selection, site identification, system design, integration with renewable sources, performance optimization, environmental impact assessment, stakeholder engagement, and compliance with regulatory standards. The project does not cover non-renewable energy solutions or unrelated sustainability initiatives.

1.2.3 Significance and Implications

Addressing this problem is crucial as it promotes renewable energy adoption, reduces carbon emissions, enhances energy security, and fosters sustainable development. Failure to address the problem may result in increased reliance on fossil fuels, environmental degradation, and missed opportunities for innovation and economic growth.

1.2.4 Quantification (if any)

The problem's magnitude is evidenced by the increasing global energy demand, rising carbon emissions, depletion of fossil fuel reserves, and the potential for CSP technology to contribute significantly to renewable energy production and sustainability goals.

1.3 Project Objectives: Design and Implementation of Eco-Friendly Concentrated Solar Power (CSP)

Objective 1: To evaluate, select, and design an eco-friendly CSP technology, ensuring optimal efficiency, scalability, and sustainability.

Objective 2: To identify and assess potential sites for the CSP plant based on solar irradiance levels, land availability, environmental considerations, and infrastructure requirements.

Objective 3: To explore and implement strategies for integrating the CSP system with other renewable energy sources, such as wind and hydropower, to enhance energy production and reliability.

Objective 4: To implement advanced control systems, tracking mechanisms, and monitoring protocols to optimize CSP system performance, maximize energy yield, and ensure long-term reliability.

1.4 Project Specification:

Technical Requirements:

1. **Technology Selection:** Adopt a CSP technology, such as parabolic trough or tower systems, emphasizing efficiency, scalability, and sustainability.
2. **Solar Irradiance Management:** Incorporate mechanisms to optimize solar irradiance absorption, conversion, and utilization across varying environmental conditions.
3. **Heat Transfer Mechanism:** Implement a reliable heat transfer fluid (e.g., molten salt or synthetic oil) system to capture, store, and transfer thermal energy efficiently.

Performance Expectations:

1. **Energy Conversion Efficiency:** Target a solar-to-electricity conversion efficiency exceeding 20% to maximize energy output and system viability.
2. **Operational Reliability:** Ensure system uptime, reliability, and performance consistency with a minimum % operational efficiency of 98%.
3. **Energy Storage Capacity:** Develop thermal energy storage solutions to store excess heat energy and facilitate continuous electricity generation during periods of low solar radiation.

Design Elements:

1. **Modular Design:** Adopt a modular system design approach to facilitate scalability, maintenance, and integration with complementary renewable energy sources.
2. **Material Selection:** Utilize high-quality, durable, and environmentally sustainable materials that withstand high temperatures, corrosion, and environmental factors.
3. **Environmental Considerations:** Incorporate eco-friendly design principles, including water conservation, habitat preservation, and low-impact construction methodologies.

Functionalities:

1. **Advanced Control Systems:** Integrate sophisticated control systems, automation technologies, and monitoring solutions to optimize energy production, efficiency, and system reliability.
2. **Solar Tracking:** Implement advanced solar tracking mechanisms (e.g., single-axis or dual-axis) to maximize solar energy capture, absorption, and utilization.
3. **Renewable Integration:** To create hybrid energy solutions and develop interfaces and protocols for seamless integration with other renewable energy systems, such as wind turbines and hydropower plants.[2]

Compatibility:

1. **Interoperability:** Ensure compatibility with existing energy infrastructure, grid systems, and renewable energy installations to facilitate integration, operation, and management.
2. **Scalability:** Design the CSP system with scalability features to effectively accommodate future expansions, technological advancements, and evolving energy demands.

Security Measures:

1. **Physical Security:** Establish stringent physical security protocols, surveillance systems, and access controls to protect critical infrastructure, assets, and personnel from potential threats and vulnerabilities.

Chapter 2

PROJECT MANAGEMENT

Our CSP project is structured over six months and segmented into phases: feasibility analysis (1 month), design and engineering (3 months), construction (4 months), and commissioning (6 months).

2.1 Project Plan:

Timeline:

- Research and Design Phase (Month 1): Understanding the requirements of the parabolic dish antenna, its materials, dimensions, and functionalities.
- Procurement Phase (Month 3): Sourcing materials, components, and necessary tools.
- Construction Phase (Month 3-4): Assembling the parabolic dish antenna, integrating the solar receivers, and testing.
- Testing and Calibration Phase (Month 5): Ensuring the parabolic dish antenna functions optimally and efficiently.
- Deployment and Maintenance Phase (Month 6 onwards): Installing the antenna and the designated components and ensuring periodic maintenance.

Tasks & Responsibilities:

- Research: Conducts market research, identifies materials, and defines specifications.
- Procurement: Responsible for sourcing materials, negotiating prices, and ensuring timely delivery.
- Construction: Engages in assembling the dish, aligning the components, and integrating the solar receivers.
- Testing: Run tests to ensure the dish meets performance criteria and conducts necessary calibrations.

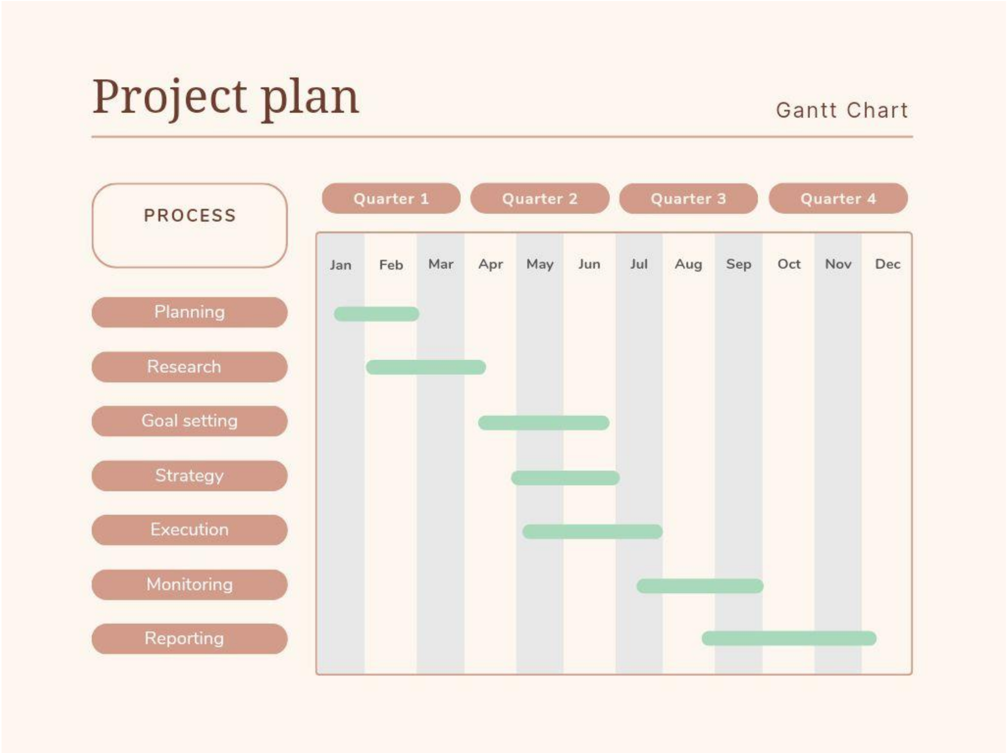

Figure 2.1: Gantt Chart

2.2 Contribution of Team Members

- Research: We ensure the parabolic dish design maximizes solar absorption and efficiency.
- Procurement: The negotiation skills and supply chain expertise guarantee the cost-effective acquisition of high-quality materials, ensuring the project remains within budget.
- Construction: Hands-on skills and experience in assembling similar structures are pivotal. We ensure the dish is built accurately to specifications, ensuring its functionality and longevity.
- Testing: Comprising individuals with a keen eye for detail, we rigorously evaluate the dish's performance, ensuring it meets or exceeds expected efficiency levels.
- Maintenance: With preventive and corrective maintenance skills, we ensure the dish operates optimally throughout its lifecycle, maximizing ROI.

2.3 Challenges and Decision Making

Challenges Faced:

- Material Sourcing Delays: Unexpected supply chain disruptions affecting the timely procurement of essential components.

- Technical Glitches: Initial tests reveal alignment issues or inefficient solar absorption rates.

- Communication: Ensured transparent team communication to address issues and promptly realign tasks if necessary.

- Problem-Solving Sessions: Regular brainstorming sessions were held to collaboratively address challenges, pooling expertise from the supervisor and team members.

Decision-Making Process:

- Identification: The team identifies the challenges and issues.
- Evaluation: A comprehensive analysis is conducted to understand the impact and possible solutions.
- Consultation: Relevant team members and stakeholders are consulted for insights and recommendations.
- Decision: A consensus-driven decision-making approach ensures all parties' buy-in.

Impact on Project Outcomes:

By addressing challenges collaboratively, the team ensured that project timelines were not significantly affected and that the final parabolic dish antenna met performance expectations.

Chapter 3

SYSTEM DESCRIPTION

Concentrated solar power (CSP) is a renewable energy technology that uses solar energy to generate electricity. Traditional photovoltaic systems convert sunlight directly into electricity, (CSP) systems use mirrors or lenses to concentrate sunlight onto a small area. CSP systems use mirrors to concentrate sunlight onto a small area.[3] This focused sunlight generates intense heat, which is then utilized to produce steam or drive a heat engine that powers a turbine, ultimately generating electricity.

They are using CSP technologies, including parabolic troughs and dish systems. Parabolic troughs use curved mirrors to focus sunlight onto a receiver tube. Dish systems employ a mirrored dish to focus sunlight onto a receiver, producing steam to drive a generator and high-temperature heat for electricity generation.

CSP offers advantages such as energy storage capabilities, allowing electricity generation even when the sun is not shining. It's a versatile and sustainable solution for large-scale power generation, contributing to the transition toward cleaner and more sustainable energy sources.

Methodology:

Step 1: First, design the CSP system with a mirror, steam drum, steam turbine, and power generation equipment.

Step 2: Design the concentrator (mirrors or heliostats) to accurately focus sunlight onto the receiver (Steam drum).

Step 3: Then, channel the high-pressure steam to the steam turbine. The turbine rotates the generator and generates Electricity.

Step 4: Implement a monitoring and control system to track the system's performance, efficiency, and maintenance needs. Continuously optimize the system.

3.1 Block Diagram of the System

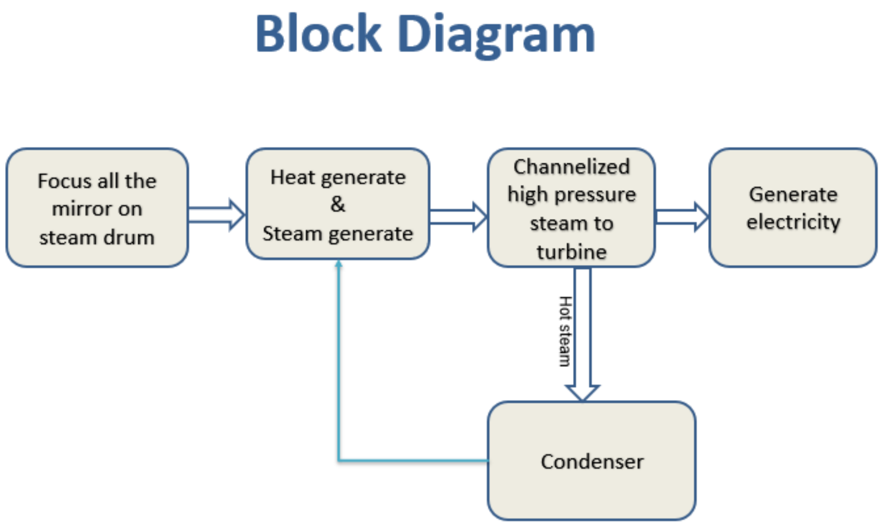

Figure 3.1: Block diagram of the system

In figure 3.1 shows the block diagram of our system. A complete overview of our system plays a very important role in building a CSP system.

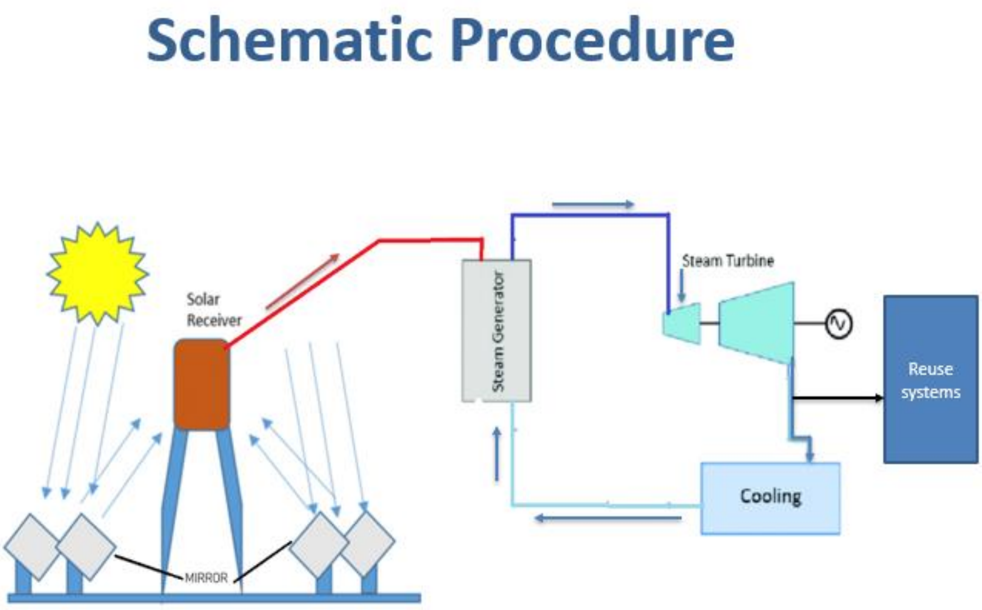

Figure 3.2: Schematic Procedure

From figure 3.2 we can see the schematic procedure from which we can get a clear idea how our system will work.

Our CSP system architecture comprises four essential blocks: Solar Collector Array, Thermal Storage System, Power Conversion Unit, and Grid Integration System.

- **Solar Collector Array:** Captures solar energy using mirrors/lenses and focuses it onto a receiver.
- **Thermal Storage System:** Stores the collected heat energy for later use, typically in molten salt or other heat storage mediums.
- **Power Conversion Unit:** Converts stored thermal energy into electricity using a heat engine, usually a steam turbine.
- **Grid Integration System:** Connects the CSP plant to the electrical grid, manages power output, and ensures compatibility with grid requirements.

3.2 Design of Each Block and Select the Best Alternative

- Focus all the mirrors on the stream drum:

1. Mirror Arrangement: Mirrors, also known as Sun-tracking mirrors, are arranged in a way that they track the sun and reflect sunlight toward a specific point, typically a receiver.

2. Receiver: The receiver is located at the focus point of the mirrors, where the concentrated sunlight is collected. In the case of steam generation, this receiver is designed to absorb the concentrated solar energy and convert it into heat.

3. Steam Generation: The intense heat absorbed by the receiver is used to heat a working fluid, often a heat-transfer fluid like molten salt or synthetic oil. This heated fluid is then used to generate steam by transferring its heat to water in a steam drum or boiler.

4. Turbine and Generator: The steam produced drives a turbine connected to a generator, converting the thermal energy into electricity.

5. Power Generation: The generator produces electricity, which can be distributed to the power grid.

- Heat generate and steam generate:

    1. Solar Concentration: Large mirrors or lenses concentrate sunlight onto a small focal point.

    The concentrated sunlight can be directed to a receiver, often located at the top of a tower or the focal point of a parabolic trough.

    2. Heat Absorption in Receiver: The receiver is designed to absorb the concentrated sunlight and convert it into heat.

    The most common type of receiver is a solar absorber, which is often filled with a heat transfer fluid, such as oil or molten salt.[4]

    The absorbed sunlight raises the temperature of the heat transfer fluid, generating high-temperature heat.

    3. Heat Transfer: The heat transfer fluid carries the absorbed solar thermal energy away from the receiver to a heat exchanger.

    In some systems, molten salt is used as the heat transfer fluid because it can effectively store and retain high temperatures.

    The heat transfer fluid exchanges heat with a working fluid (e.g., water or synthetic oil) in the heat exchanger.

    4. Steam Generation: The working fluid, now heated by the concentrated sunlight, generates steam.

    The steam can then be used to drive a turbine connected to an electricity generator, producing electricity.[5]

    Alternatively, the steam can be used for various industrial processes or applications.

- Channelized high-pressure stream to turbine:

1. Sun-tracking mirrors are specialized mirrors that track the sun and reflect sunlight onto a focal point, creating an intensely concentrated beam.

2. Receiver: The concentrated sunlight is directed to a receiver, typically positioned at the focal point, where it generates high temperatures.

3. Heat Transfer Fluid: A channelized high-pressure stream of heat transfer fluid circulates through the receiver, absorbing the intense thermal energy.

4. Turbine: The pressurized heat transfer fluid is then directed to a turbine, where its high-pressure release drives the turbine blades, generating electricity.

- Condenser:

1. Condensation: In the first step, the high-temperature vapor or steam carrying the thermal energy from the concentrated sunlight undergoes condensation.

The condenser provides a controlled environment where the hot vapor releases its heat energy, causing it to transform into a liquid state.

2. Heat Transfer: During this phase, the heat energy extracted from the vapor is transferred to a heat exchange medium.

This transfer ensures efficient thermal energy utilization, allowing it to be harnessed for various applications, such as power generation or industrial processes.

3. Coolant Circulation: The condensed liquid is then circulated through a cooling system or coolant loop, preventing it from reaching high temperatures again.

This circulation is essential for maintaining the efficiency of the CSP system, as it prevents overheating and ensures a continuous and stable energy conversion process.

4. Return to Solar Receiver: The cooled liquid, having released its heat energy, is returned to the solar receiver or another part of the CSP system to repeat the cycle.

By returning to the solar receiver, the liquid is ready to absorb more concentrated sunlight and restart the process of vaporization and condensation.

- Generate electricity:

1. Solar Concentration: In this initial step, sunlight is collected and concentrated using mirrors or lenses to focus the solar energy onto a small area.

Concentrating the sunlight increases its intensity, creating high temperatures at the focal point.

2. Heat Transfer: Concentrated sunlight is then used to heat a transfer fluid, such as molten salt or synthetic oil, within a solar receiver.

This fluid absorbs the intense heat, reaching high temperatures exceeding 500 degrees Celsius.

3. Energy Storage or Thermal Transfer: The high-temperature fluid is stored for later use or directly used to produce steam.

Energy storage can involve storing the hot fluid in insulated tanks, allowing for continuous power generation even during periods without sunlight.

4. Electricity Generation: The high-temperature fluid or steam is employed to drive a turbine connected to an electricity generator.

As the turbine spins, it generates electricity through the rotation of the generator.

The produced electricity can be distributed to the grid for various applications.

3.3 System Implementation

Step 1: We first choose mirrors and a parabolic dish antenna for the Solar Collector Array. Focus on the receiver while positioning every mirror on the parabolic antenna.

Step 2: The fluid (water) is held in a tin can, the receiver, in this demonstration.

Step 3: Hot steam is sent from the receiver to the steam turbine via a conduit, which primarily centrifuges the motor to produce energy.

Step 4: A heat sensor is installed in the receiver to track temperature variations based on meteorological conditions.

Chapter 4

SYSTEM TESTING AND ANALYSIS

4.1 Systematic Approach to System Testing

A systematic approach will be utilized to guarantee comprehensive testing of the designed solution in the context of the concentrated solar power (CSP) system deployment. Prototype testing and simulation will be combined, depending on the components under evaluation.

A physical testing setup for the prototype components will be constructed to confirm the developed solution's performance, dependability, and functionality. Real-world circumstances will be used to evaluate how the system responds to environmental factors like temperature and sunshine intensity.

At the same time, models will be used to assess some of the system's features that would be difficult to duplicate in an actual prototype. These simulations will support a thorough understanding of system behavior by predicting various scenarios.

4.2.1 Unit Testing:

- **Focus testing:**

  To ensure the focus point of the antenna we move a flat surface forth and backward. Where the maximum reflection combines and most of the heat generates.

  In our meticulous focus testing, a configuration of 457 mirrors meticulously positioned within a precisely designed parabolic dish is utilized. This arrangement is engineered to effectively concentrate and direct sunlight onto a specific area of interest. The objective is to observe and quantify the resulting temperature variations. Through rigorous experimentation, we have determined that the maximum temperature achieved in this testing scenario reached an impressive 168 degrees Celsius. Figure 4.1 shows that the mirrors used in our system are focusing to a specific area. This detailed setup allows for a comprehensive examination of the mirrors' collective impact on solar irradiation and temperature generation.

Figure 4.1: Focus test on parabolic dis

- **Maximum heat testing:**
  Using the temperature sensor, the maximum heat is measured.

  In the specific area where we monitor the focus of all 457 mirrors, temperature readings are obtained using a dedicated temperature sensor. Despite an anticipated temperature of 300 degrees Celsius, some technical glitches prevented us from capturing this value accurately. However, we successfully recorded temperatures reaching 180 degrees Celsius. In figure 4.2 we can see how the temperature sensor is getting in the focused area of our system. Notably, we designed and integrated an Arduino-based temperature measuring sensor into the project.

  This Arduino sensor serves a critical role in future applications. It allows us to precisely measure temperatures, offering the flexibility to set thresholds for automated responses. For instance, if a predetermined temperature is reached, the sensor can trigger alerts or even control the solar system, enabling us to regulate its operation. To enhance our monitoring capabilities, we've also incorporated a heat measurement sensor into the project, providing a comprehensive approach to temperature control and management in the solar setup.

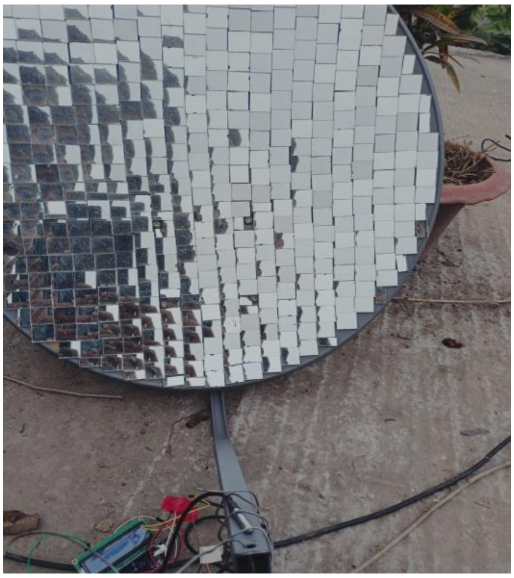

Figure 4.2: Heat test

- **Heat absorption:**
  Aluminum is known for its high thermal conductivity. The thickness of aluminum used in the can is about 0.25 to 0.3 millimeters (mm).

  In our comprehensive heat absorption testing, the focused heat generated by the 457 mirrors in the parabolic dish is directed towards a steam drum, optimizing the conversion of thermal energy into steam. This process builds upon the intricate setup discussed earlier, where we meticulously measure and monitor temperatures using our Arduino-based temperature sensor. In figure 4.3 we can see our steam drum as steam generator and 5v dc motor.

  The heat absorption mechanism involves the precise alignment of mirrors to concentrate sunlight onto the steam drum. This strategic focus ensures an efficient transfer of thermal energy, facilitating the rapid production of steam. This step is crucial as it contributes to the overall evaluation of the solar system's performance, particularly in terms of its ability to harness and convert solar energy into a usable form.

  Furthermore, the integration of the temperature sensor adds an extra layer of sophistication to the heat absorption process. By continuously monitoring temperatures within the steam drum, we can fine-tune the system for optimal steam generation. This detailed approach not only enhances the accuracy of our measurements but also provides valuable insights into the efficiency and reliability of the solar power setup under varying conditions.[6]

Figure 4.3: Heat absorption

- **Pressure testing:**

  The steam drum was completely sealed and the water vapor behaves ideally, the pressure inside the can after 100ml of water evaporates at 150°C for 20 minutes will create 1.084 bar. Atmospheric pressure during testing was 1013 mbar, it may change according to geographical change.

  Here's a breakdown of the calculations:

  1. Moles of water evaporated:

     - Mass of water evaporated = 100ml * 1g/ml = 100g
     - Moles of water evaporated = 100g / 18.015 g/mol = 5.55 mol

2. Volume of water vapor:

- Ideal gas law: PV = nRT
- Rearrange for volume: V = nRT/P
- T = 150°C + 273.15 = 423.15 K
- P = atmospheric pressure = 1013 mbar = 1.013 bar
- V = 5.55 mol * 461.5 J/kg K * 423.15 K / 1.013 bar
- V ≈ 104.7 m^3

3. Total pressure in the can:

- Assuming all the water vapor remains in the can, the total volume of gas is the volume of the can (250ml) plus the volume of the water vapor.
- Total pressure = (atmospheric pressure + pressure due to water vapor)
- Pressure due to water vapor = (volume of water vapor / volume of can) * atmospheric pressure
- Total pressure ≈ 1.013 bar + (104.7 m^3 / 0.250 m^3) * 1.013 bar
- Total pressure ≈ 1.084 bar

We use this pressure to rotate a 5V DC motor and get 3.5-4V on average. As per it is only test basis. The increase of radial of the antenna and the volume of the steam drum and using low-pressure steam turbine will generate more electricity.[7]

- **Electricity generation:**
  From this system, we get 150-170 degrees Celsius from the steam drum and 1.08 bar pressure and using these from the DC motor, we get 3.5V to 4V on average. A low-pressure steam engine requires 4 to 5 bar pressures to generate Electricity. [8]
  However, we got a 1.08 bar in our system. Adding more mirrors and changing the volume of the steam drum pressure is achievable. From figure 4.4 we can see that by applying heat to our steam drum, steam is generated and the DC motor rotates and electricity is generated.

The Rampal power plant in Bangladesh needs a temperature of 1300 degrees Celsius to generate 1320 megawatts of Electricity. We need much coal as fuel in production. However, if we use our system there, we can do it at a much lower cost. We have mathematically analyzed that 1 square meter provides about 450 to 500 degrees Celsius. So, if we want to produce 1300 degrees, 4 square meters of parabolic antenna or four 1 square meter antenna will fulfil the requirement. It is eco-friendly and cost-effective because here we can get the heat from the sun, and we do not need coal as fuel. [9]

Figure 4.4: Electricity generation

4.2.2 Integration Testing:

Every part of our CSP system is linked to every other part. Every ray that the antenna reflects is directed straight onto the receiving surface. We shall gate the surface temperature at 150–170 degrees Celsius since the efficiency is not 100%. The temperature will rise if all the mirrors correctly reflect to the spot. The water in the receiver boils due to the heat. 100ml of water evaporated at 150°C for 20 minutes will create 1.084 bar. Atmospheric pressure 1013 mbar.

Using these from the DC motor, we get 3.5V to 4V electricity on average. In the figure 4.5 we can see the work and output of our complete system. However, because we are utilizing a fan in our prototype, the pressured steam occasionally needs to be more robust to rotate the motor to its full potential. Outside winds and other disasters may bring on this problem. A steam turbine will solve this problem; we use these alternatives for supply chain shortages.

Figure 4.5: Integration testing

4.2.3 System Testing:

Our CSP system's parts are all interacting with one another correctly. The receiver surface is immediately hit by every one of the antenna's reflected photons. We obtain between 170 and 180 degrees Celsius at the surface since the efficiency is not 100%. The temperature will rise if every mirror accurately reflects the spot. The receiver's water boils because of the heat. The monitor continually receives data from the temperature sensor. The steam turbine rotates the motor, which gets the steamed water at high pressure. However, the pressured steam in our prototype, which we need to move the engine to generate energy, occasionally needs more pressure. This problem is caused by external wind and other disasters.[10]

4.3 Data Analysis and Discussion:

4.3.1 Mathematical analysis:

Area of the Dish:

The area A of the parabolic dish can be calculated using:

$$A= \pi * r^2$$

where is the radius of the dish.

Focal Length of the Dish:

The focal length f using: of the parabolic dish is related to its depth and can be determined using:

$$F= D^2 / 16 * depth$$

where D is the diameter of the parabolic dish and depth is the depth of the dish.

Hear as per our project data,

D=0.67 meter

Depth = 0.076 meter

R = 0.335-meter square.

Area = 3.1416 *(0.335) ^2

Area = 0.35-meter square

Focal length = (0.67) ^2 / (16 * 0.076)

Focal length = 0.369

Power produced by the CSP P:

P = 4.π.f ^2 / A

P = 4 * 3.1416 * (0.369) ^2 / 0.35

P= 4 * 3.1416 *0.136 / 0.352

P≈ 4.88 watts

So, we get in mathematical 5 watts.

As per our excrement,

0.35 meter square produce = 168 ℃

1 meter square produce = (168 * 0.35) ℃

= 480 ℃

Now calculated the amount of heat in per mirror,

So, 457 mirrors produce 168 ℃

So, 1 mirror produce (168 * 457) ℃

So, per pieces mirror produce 0.36 ℃

Finally, we can say how big our interface is or how much area we will get. According to that we can implement it in our cooking system. For example, in case of cooking system we need 100-degree Celsius temperature, how much interface solar power we need to get 100 degrees Celsius If we can make this calculation, we can finally say that to get a temperature of 100 degrees, we need to make a solar power of minimum 0.25 square meter and we can make it a folding system if we want, it can be easily carried anywhere.

4.3.2 CSP system analysis:

(CSP) - Throughput:

CSP Type	Maximum Throughput (MWh/year/acre)	Key Factors Affecting Throughput
Parabolic trough	45-55	Direct normal irradiance (DNI), collector efficiency, receiver temperature, thermal energy storage capacity.
Solar power tower	50-75	DNI, heliostat field efficiency, receiver temperature, thermal energy storage capacity.
Linear Fresnel reflector	40-45	DNI, collector efficiency, receiver temperature, thermal energy storage capacity.
Dish Stirling	50-100	DNI, dish size, Stirling engine efficiency, thermal energy storage capacity.

Table 4.1: CSP throughput

(CSP) – Latency:

Latency, in the context of CSP, refers to the time delay between a change in solar input. cloud cover, sunrise/sunset and the corresponding response in power output.

CSP Technology	Latency (minutes)
Parabolic Trough	10-30
Linear Fresnel	5-20
Tower	1-5

Factor	Impact on Latency
Thermal storage capacity	Higher capacity = higher latency
HTF properties (specific heat, density)	Higher specific heat = higher latency
Plant design (pipeline lengths, component placement)	Longer pipelines = higher latency
Control system sophistication	More advanced systems = lower latency

Table 4.2: Factors Affecting Latency

(CSP) - Maximum Power Consumption and Relevant Information:

Power Consumption in a CSP System:

Various components in a CSP system contribute to its overall power consumption:

1.Mirrors: Tracking and adjusting the mirrors require energy, especially in large-scale plants with hundreds or thousands of individual mirrors.

2.Heat transfer fluids: Pumping the heat transfer fluid (HTF) through the system to the receiver and back to the heat exchanger consumes energy.

3.Power conversion unit: The turbine and generator used to convert thermal energy into electricity require power for operation and control.

4.Auxiliary systems: Pumps, fans, maintenance equipment, and control systems also contribute to total power consumption.

Factors Affecting Maximum Power Consumption:

These factors significantly influence the maximum power consumption of a CSP system:

1.System size: Larger CSP plants tend to have higher total power consumption due to larger mirrors, longer HTF pipelines, and larger power conversion units.
2. Technology type: Different CSP technologies (parabolic trough, linear Fresnel, tower) have varying power consumption needs based on their tracking mechanisms, HTF types, and operating temperatures.

3.Efficiency: More efficient systems consume less energy per unit of energy produced.

4.Operating conditions: Ambient temperature, irradiation levels, and system cleanliness impact the power required for mirror tracking, HTF pumping, and other functions.

Components	Type of power consumption (MW)	Example System Size
Mirror tracking	0.5-1.5	100 MW
HTF pumping	1-2	100 MW
Power conversion unit	2-5	100 MW
Auxiliary systems	0.5-1	100 MW
Total Maximum Consumption	4-9.5	100 MW

Table 4.3: Power Consumption Data

4.3.3 Solar vs CSP Comparison:

Feature	Photovoltaic Solar Panels (PV)	Concentrated Solar Power (CSP)
Technology	Direct conversion of sunlight into electricity (Photovoltaic)	Concentrates sunlight using mirrors to heat fluid, generating electricity
Efficiency	15-22% average	20-40% potential
Cost	Higher investment	Lower investment
Dispatchability	No	Yes, with thermal energy storage

Scalability	Good for both small and large installations.	Ideal for large-scale power generation>
Environmental Impact	Both significantly lower than fossil fuels.	Both significantly lower than fossil fuels.
Advantages	Simple technology, low maintenance, low environmental impact, versatile	Higher potential efficiency, dispatchable power, integration with other applications, potentially lower long-term cost
Land Use	Higher	Significantly higher (mirror fields)
Ideal for	Rooftop installations, dispersed generation, more compact projects, and a wide range of uses	Large-scale power production, areas with lots of sunshine and clear skies, projects requiring power that can be dispatched, or heat that requires a high temperature.
Reliability	Dependable when there is constant sunlight, but the weather and time of day have an impact on power generation.	Can provide more consistent power output through the use of thermal energy storage, reducing the impact of intermittent sunlight.

Table 4.4: Solar vs CSP Comparison

Chapter 5

CONCLUSION AND RECOMMENDATION

In conclusion, this Capstone proposal project on Concentrated Solar Power (CSP) system design, implementation, and optimization demonstrates significant achievements, contributions, and potential benefits to stakeholders, the renewable energy sector, and society. By addressing key objectives, leveraging advanced technologies, promoting sustainability, and fostering collaboration, the project lays a foundation for future research, development, deployment, and commercialization of CSP systems, contributing to a sustainable, resilient, and inclusive energy future for all.

5.1 Conclusion

The objective of this project is to construct a 10 W Concentrated Solar Power (CSP) system, utilizing mirrors or heliostats to concentrate sunlight onto a receiver. In our setup, we employed 457 mirrors, resulting in a temperature of approximately 168°C. This temperature was sufficient to produce steam at a pressure of 1.08 bar. However, due to the unavailability of a dedicated steam drum, we improvised by using tin cans, introducing some errors into the process.

To harness the pressure generated, we incorporated a DC motor, which effectively produced around 3.2 volts of electricity. It's worth noting that, given the absence of steam engines in our country, this alternative approach proved viable. While the use of steam could have ideally helped us reach our target, various challenges and errors in utilizing our primary source prompted us to generate 3.3-volt electricity through this unique setup.

By producing high-pressure steam that powers a turbine to produce electricity, the device investigates various uses, such as melting metal and cooking, while mitigating carbon emissions. With a focus on economy, efficiency, and sustainability, the project combines CSP with renewable energy sources, including hydropower and wind. The process includes steam turbine operation, precise sunlight concentration, systematic design, and ongoing optimization via a monitoring and control system. This all-encompassing strategy tackles issues related to global sustainability and offers a flexible, environmentally beneficial energy option with a wide range of uses.

Problem Addressed:

- The primary objective of this capstone project is to conceptualize, design, implement, and optimize a concentrated solar power (CSP) system. The project aimed to meet the increasing need for sustainable energy solutions by harnessing solar energy using sophisticated Concentrated Solar Power (CSP) technologies.

Objectives Achieved:

1. System Design: Successfully developed a comprehensive CSP system design, incorporating solar tracking mechanisms, temperature sensing systems, thermal storage solutions, and power generation units.
2. Implementation: Translated the conceptual design into tangible components, including site selection, procurement, construction, installation, testing, and commissioning.
3. Optimization: Implemented efficiency optimization strategies, control algorithms, and operational protocols to maximize energy capture, conversion efficiency, and system performance.

Impact and Significance:

- The proposed CSP project contributes significantly to the renewable energy sector by harnessing solar energy, reducing carbon emissions, promoting sustainability, and diversifying energy sources. The project's successful implementation offers a scalable, efficient, cost-effective solution to meet growing energy demands, enhance energy security, and mitigate environmental impacts. Furthermore, the project fosters economic development, job creation, technological innovation, and stakeholder engagement, aligning with global sustainability goals and climate change mitigation efforts.

5.2 Future Recommendation

The Concentrated Solar Power (CSP) project has laid a robust foundation by addressing critical design, implementation, and optimization aspects. However, several areas warrant further exploration, research, and development to enhance CSP technology's efficiency, scalability, and applicability. Here's a comprehensive overview of the future work scope based on the CSP project:

1. Heat Storage and Utilization:

Thermal Energy Storage: Explore advanced thermal energy storage solutions to store excess heat generated during peak sunlight hours for later use during low sunlight or increased energy demand.

Heat Utilization: Identify potential applications and sectors where the generated heat can be utilized, such as industrial processes, cocking, district heating, desalination, agriculture, or combined heat and power (CHP) systems.

Research and Development: Investigate advanced heat transfer mechanisms, techniques, and materials to enhance the efficiency, reliability, and performance of heat generation processes.

Heat Exchanger Design: Explore innovative heat exchanger designs, configurations, and materials to optimize heat transfer rates, minimize energy losses, and improve system efficiency.

2. Technological Advancements:

Advanced Solar Collectors: Investigate next-generation solar collector technologies, materials, and configurations to improve efficiency, durability, and cost-effectiveness.

Power Conversion Efficiency: Explore advanced power conversion technologies, heat-to-power conversion systems, and energy conversion efficiency enhancement techniques to optimize electricity generation and system performance.

3. System Optimization and Integration:

Smart Grid Integration: Develop innovative grid integration solutions, demand-side management strategies, and grid stability enhancement techniques to facilitate seamless integration, synchronization, and operation with existing electrical grids.

Hybrid CSP Systems: Investigate hybrid CSP systems, integrating CSP with other renewable energy sources, energy storage technologies, and complementary power generation technologies to enhance reliability, flexibility, and overall system performance.

Operational Optimization: Implement advanced control algorithms, predictive maintenance strategies, and real-time monitoring systems to optimize operational performance, energy capture, and system reliability.

4. Research and Development:

Material Science: Conduct research in material science, nanotechnology, and metallurgy to develop advanced materials, coatings, and components capable of withstanding high temperatures, corrosive environments, and prolonged operational cycles.

Innovative Cooling Solutions: Investigate innovative cooling technologies, passive cooling techniques, and thermal management strategies to maintain optimal operating temperatures, enhance system efficiency, and extend component lifespan.

5. Policy, Regulation, and Market Development:

Policy Advocacy: Advocate for supportive policies, regulatory frameworks, financial incentives, and market mechanisms to accelerate CSP deployment, reduce costs, and promote market competitiveness.

Standardization and Certification: Establish industry standards, best practices, and certification protocols for CSP technologies, ensuring safety, reliability, performance, and compliance with regulatory requirements.

Market Development: Foster collaboration among industry stakeholders, investors, policymakers, and research institutions to stimulate market demand, investment, innovation, and commercialization of CSP technologies.

6. Environmental and Sustainability Considerations:

Environmental Impact Assessment: Conduct comprehensive ecological and sustainability evaluations to assess our CSP heat generation project's environmental, social, and economic implications.

Resource Efficiency: Implement resource efficiency practices, waste minimization strategies, and circular economy principles to optimize resource utilization, reduce waste generation, and enhance sustainability within your CSP project lifecycle.

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