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Concentrated Solar Thermal Power Plant

Parabolic Dish System

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Abstract: Solar light has been captured through the continuous advancement of photovoltaic technology. However, concentrated solar heat proves to be more efficient and capable of generating dispatchable power. This initiative marks the beginning of harnessing concentrated solar heat energy for both domestic and industrial purposes. The utilization of a parabolic dish is employed to concentrate solar power, showcasing a significant step towards maximizing the potential of solar energy in various applications. Here at receiver sterling engine is used to generate electricity.
Parabolic Dish Solar Concentrators have demonstrated remarkable conversion efficiencies and can operate at high temperatures, reaching around 750°C with an annual efficiency of 23%-29% at peak levels. Ongoing research and testing of prototypes globally indicate the potential of this technology. Despite its advantages, Dish Engine Technology entails high investment costs, nearly double that of parabolic troughs. The focus of Dish Engine system industries and initiatives predominantly lies in the US and Europe. However, the significant potential for utilizing Parabolic Dish Concentrators across various industries, particularly in India, underscores the importance of continued research and development efforts.

Keywords: Concentrated solar power (CSP), Dish Engine Technology, Parabolic Dish Solar Concentrators, renewable sources.

I. INTRODUCTION

Energy is a vital necessity for sustaining life, with the sun being the primary source of energy for Earth. The intricate process of converting solar energy into different forms plays a crucial role in supporting life on our planet. The evolution of human capacity to harness energy from various sources has significantly impacted human life and civilization, especially evident during the Industrial Revolution, which brought about substantial changes in energy conversion and utilization patterns. The United States has the highest per capita energy consumption globally, while India ranks sixth in energy demand, accounting for 3.5% of the world's commercial energy demand in 2001. India's lower per capita energy consumption compared to many countries is due to its large population. Projections indicate that by 2030, India's population will surpass China's, leading to a significant increase in energy consumption, potentially reaching one-third of global demand by 2050. The challenges posed by the energy crisis and global warming emphasize the urgent need for cleaner and more sustainable methods of sustaining life. Solar energy technology, particularly through Solar Photovoltaic and Solar Thermal Systems, plays a crucial role in addressing these challenges. Solar Thermal Systems, including Flat Plate and Concentrator types, offer promising solutions for overcoming energy crises and environmental issues. The utilization of Solar Concentrator Technology in various industries, especially the Process Industry, presents significant potential for medium temperature applications and is gaining attention from researchers and developers, highlighting the need for further research and development in this field.

Concentrating Solar Thermal Power (CSP) technology has reached a significant level of commercial maturity, with four primary technologies in use: trough concentrators, tower/heliostat systems, linear Fresnel concentrators, and dish concentrators, with deployment and commercial maturity in declining order. The deployment rate of these technologies has been increasing at approximately 40% annually.

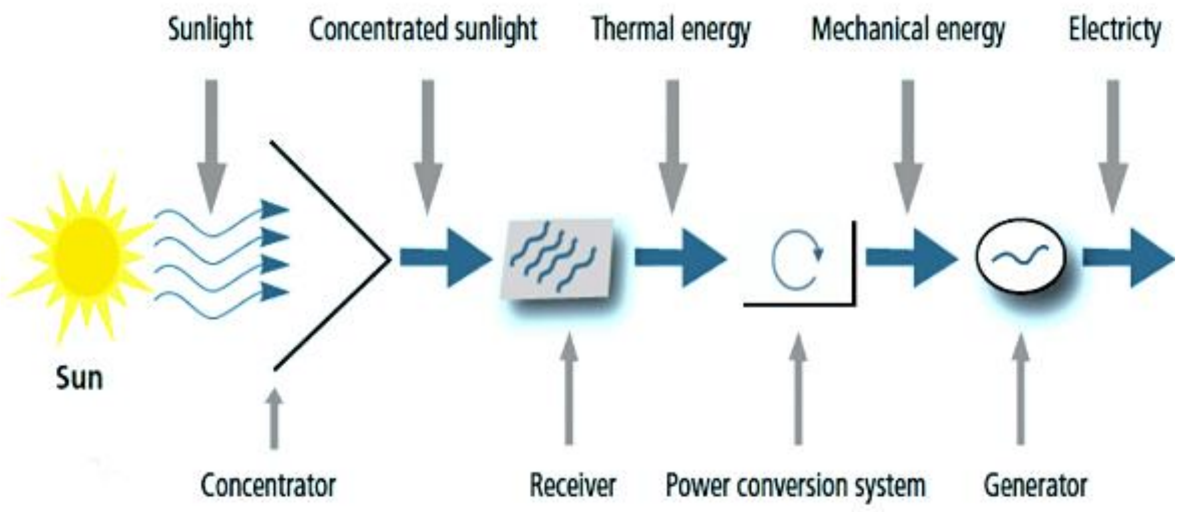

Fig 1: Solar Energy to Electrical Energy conversion process

Solar generation technologies, encompassing photovoltaic systems, are rapidly evolving and are poised to play a significant role in the future energy landscape. While currently a minor component of the overall energy mix, Concentrating Solar Power (CSP) technologies are gaining prominence for their potential to offer substantial and reliable energy storage within the system. CSP systems utilize mirrors to concentrate sunlight onto receivers that capture and convert solar energy into heat, subsequently used to generate electricity through steam turbines or heat engines driving generators. Unlike photovoltaic cells or flat plate collectors, CSP technologies are unable to harness the diffuse solar irradiation resulting from the scattering of direct sunlight by atmospheric elements like clouds, particles, or molecules, as this diffuse light cannot be effectively concentrated.

II. Technology

A solar dish system employs a dish-shaped concentrator, akin to a satellite dish, to reflect and concentrate solar radiation onto a receiver positioned at the focal point. This receiver typically houses a Stirling engine, a type of heat engine that operates by cyclic compression and expansion of air or other gas at different temperature levels, converting the concentrated solar heat into mechanical power. The Stirling engine's design allows for efficient energy conversion, making it a key component in solar dish systems for generating electricity.

III. Literature Review

Concentrating solar power (CSP) potential and methods to advance this technology in China has been investigated by Hang et al. A huge CSP plant at Wilayat Duqum, Oman, which gets exceptionally strong solar radiation throughout the year, is evaluated by Charabi and Gastli. A complete economic analysis of solar thermal energy generation in some sites in India has been conducted by Purohit and Purohit. Arora looked at the viability of CSP plants in the Thar Desert area of Rajasthan, India. TES system included in CSP facilities has been surveyed by Kuravi et al. A prospective valuation of solar thermal plants for energy production in West Africa has been reported by Ramde et al. Receiver efficiency in STP plants has been studied by Benammar et al, who looked at how factors like surface area and temperature affected performance. A hybrid concept of the solar through and gas turbine has been designed by Turchi and Ma to improve solar thermal plant power production efficiency while dropping gas heat rate.

IV. Materials required

The parabolic dish design was created utilizing SolidWorks software. Many different available paraboloid shape dishes were considered but finally Dish Network Satellite dish was selected as it offers perfect shape required.

Measurements

1. Diameter: 80 cm

2. Height from center of dish(C)= 11.11 cm

   Theoretical focal point
   $F= D^2 /16C$
   F=81cm

Glass Mirror

Different reflective materials were considered such as acrylic mirrors, Aluminium sheets and glass mirrors. Finally, glass mirrors were chosen as the reflective material for the following reasons:

- Better reflectivity
- Cheaper
- Scratch resistant
- No oxide formation
- Durability
- Square shaped mirrors of size 3cm X 3cm.
- The reflecting surface consists of 362 such mirrors.

V. METHODOLOGY

The experimental setup is based on the working flow diagram shown in the below flowchart.

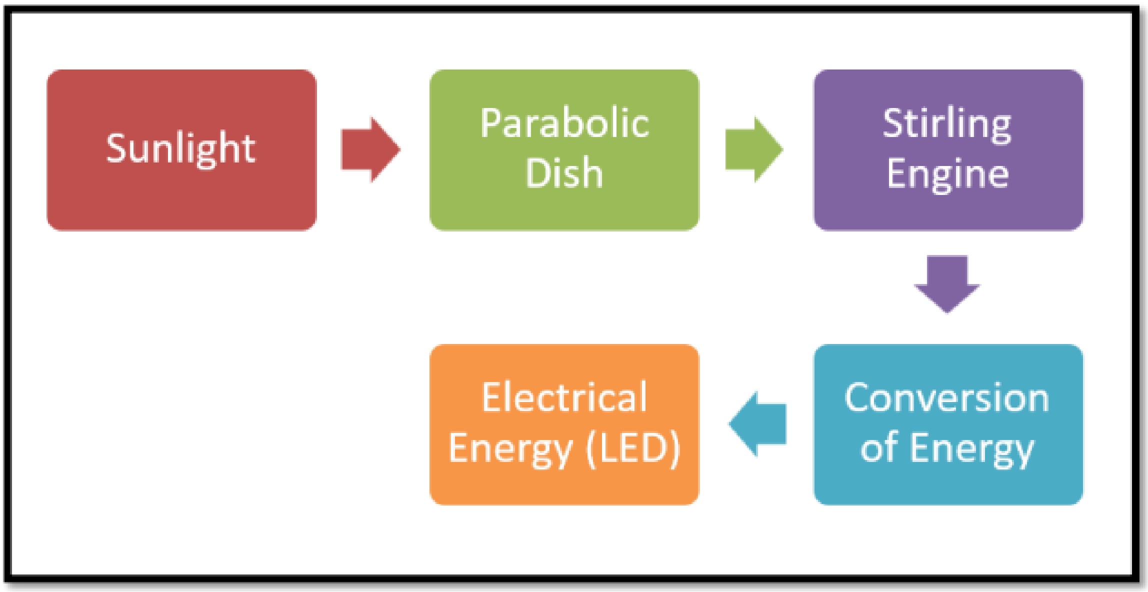

Fig 2: Working flow diagram

Parabolic Dish:
The working principle of a parabolic dish in Concentrated Solar Power (CSP) involves the use of curved mirrors to concentrate sunlight onto a focal point. Here's a detailed explanation of how it works:
Parabolic Shape: The parabolic dish is constructed with a curved surface shaped like a parabola. This shape is specifically designed to focus incoming sunlight onto a single point, known as the focal point. This parabolic dish is characterized by its unique shape, known as a paraboloid. It resembles a shallow dish or bowl with a curved surface. The surface of the parabolic dish is formed in such a way that it follows the geometric shape of a parabola, which is a curve defined by the mathematical equation $y = ax^2$.

Focal Point:
The focal point of the parabolic dish is a single point located at the centre of the dish's curvature. All incoming sunlight that strikes the reflective surface of the dish is redirected towards this focal point. The focal point is where the concentrated sunlight reaches its maximum intensity, making it the ideal location for capturing solar energy. Here we used Satellite Dish as a parabolic shape.

Mirrors or reflective surface Mirror Reflectivity:
Reflective materials used in parabolic dish Concentrated Solar Power (CSP) systems are crucial for efficiently directing sunlight towards the focal point of the dish. These materials need to possess high reflectivity, durability, and resistance to environmental degradation. The surface of the parabolic dish is covered with highly reflective material, typically mirrors or reflective film. This material efficiently reflects sunlight and directs it towards the focal point.

Reflective Coatings:
Aluminium Reflective Coatings: Aluminium is one of the most common materials used for reflective coatings due to its high reflectivity across the solar spectrum. It is applied to the surface of mirrors using techniques such as vacuum deposition or chemical vapor deposition.
Silver Reflective Coatings: Silver coatings offer even higher reflectivity than aluminium but are more expensive and susceptible to tarnishing or corrosion.
Here we used small Mirrors of 3*3 cm mounted all over satellite dish.

Supporting structure
Metal stand is being used here as a supporting structure for PARABOLIC DISH and it is constructed in such a way that DISH can be easily tracked to sun manually.
Receiver Positioned at the focal point is a receiver that captures the concentrated solar energy. The receiver here used is a Stirling Engine, it is a mechanical device which generates mechanical motion from thermal energy and further can be used to drive the generator which will produce electrical energy.

Heat Transfer The concentrated sunlight falls on tube of Stirling engine where expansion of gases takes place as the gases gets heated and further the gases gets cooled down and it gets compressed so this motion will drive the shaft leading to the mechanical motion in Stirling engine which can drive the generator.

Electricity Generation- In some CSP systems, the heated working fluid is used to generate steam, which then drives a turbine connected to a generator to produce electricity. Alternatively, the heat can be used directly in industrial processes or for other thermal applications.

Generation of Electricity- The rotational motion of the Stirling engine will drive the generator leading to production of electricity.

VI. Output results

Output of LED

Power = Voltage * Current
Voltage = 1.8 V
Current = 1.1A
W = 2 watt

VII. Conclusion

Concentrated solar power plants have great potential for supplying and fulfilling a significant energy demand in near future. The excellent thing about CSP is the clean and carbon emission free energy. The portfolio of CSP technologies comprises of mature parabolic trough technology, Linear Fresnel System and Central receiver Tower systems. The Paraboloid dish system have high solar to electricity conversion efficiencies but not tested for large industrial scale. The development of CSP based power plants in India is not very inspiring and needs proper research focusing and adapting Indian conditions.

The CSP technology is actually more efficient than photovoltaic technology. This field requires more research. Stirling cycle has been used for generation of electricity with usage of gas and air. Now we have produced only 1-2 watts of power which is relatively very low compared to the amount of energy we are getting from the sun and also considering the cost. But at industrial level with precise design of Stirling Engine, the efficiency can highly be increased. Hence power can be generated in terms of kilowatts and megawatts if properly and efficiently designed which will be cost effective as well as it will reduce the dependence on non-renewable energy sources.

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