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A Study on Solar Collectors and Thermal Energy Storage in Solar Thermal Applications.

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Abstract: The following paper will outline the accomplishments that have been made with the solar parabolic trough collector. The topic will be ruled out after reviewing numerous documents that have not been published yet. Solar parabolic troughs are one type of solar collector system. Solar energy is one of the most readily available clean kinds of renewable energy. Many methods have been developed in India to collect energy from various renewable sources, but the most exciting challenge is to extract as much thermal energy as possible from solar radiation. This study discusses the performance and potential of SPTCs. It also discusses the many applications of solar energy, such as air conditioning, desalination, refrigeration, industrial heating, and power generation. This report will be valuable to researchers working on solar energy with parabolic trough collectors.

Index Terms - **- Solar parabolic Trough, Solar energy, Solar Tracking System, Thermal Energy, Solar Collectors.**

I. INTRODUCTION

Despite incidents solar energy is abundant, but just a small portion of it is being utilized. The upper atmosphere of the earth receives 174000 Terawatts of incoming solar heat. The remaining portion is absorbed by waterways, the sky, and terrain, with around 30% of it reflected in aerospace. In 2013, the mean power consumption globally was 12.3 terawatts or the total energy consumed worldwide [1]. The demand for solar power harvesting techniques is rising as a result of the apparent energy crisis and the need for green energy. In addition to being non-conventional, solar energy is also numerous, non-polluting, and free. The most popular method of using solar power is through solar panels. Due to the sun's varying position about the earth's axis, solar tracking is essential for the panel to consume more light energy even with the variation in the positioning of the sun.
India is making significant progress in the development of solar power facilities. Currently, 58 solar trough power facilities have undergone environmental assessments. India receives a vast amount of solar power, estimated to be around 5000 trillion kWh each year, with an average daily global radiation of approximately 5 kWh/m2. One study conducted by the National Renewable Energy Laboratory in April 2013 showed that South India receives an average of more than 7.5 kWh/m2 of solar radiation per day throughout the winter[2]. Many countries are now investing in solar power facilities to generate electricity. The Energy and Resources Institute reports that India's current power capacity is 13,402 MW, with a target of achieving 800,000 MW by 2030. Renewable energy will play a significant role in meeting this goal.
The solar collector absorbs solar power and converts it to heat, which is then transferred to the working fluid. The working fluid might be air, water, oil, or some organic solvents. The heat energy in the working fluid of the solar collector may be used directly for a variety of purposes. There are several types of solar collectors, including the flat-plate collector with reflectors, the Parabolic Trough Collector (PTC), the compound parabolic collector, and the Fresnel lens concentrating collector. Flat plate collectors are mostly utilized for hot water generation because of their temperature range of 120-140 °C. In PTC, the temperature of the focus line or absorber tube can reach 350-400 degrees Celsius. Solar collector potential is determined by the concentration ratio, which compares the aperture's effective area to the absorber's surface area. A traditional power plant often requires a large quantity of nonrenewable energy sources such as coal or petroleum products; hence, using excess renewable energy minimizes nonrenewable energy consumption, resulting in less pollution. The harvest of surplus solar power leads to future advances. Because the PTC absorbs more heat than the flat plate collector, researchers have attempted to do further research on the PTC and here we discuss all the advancement in SPTCs.

Solar collector-Solar collectors are devices that gather and concentrate solar energy from the sun. These systems are mostly used for active solar heating and are capable of heating water for personal use and can say they are used for household purposes.
A solar collector is essentially a flat box made up of three major parts: a transparent cover, tubes that deliver coolant, and an insulated rear plate. The solar collector operates on the greenhouse effect concept, with solar energy impacting on the transparent surface of the solar collector being transferred through this surface. The interior of the solar collector is normally evacuated, and the energy held inside it is effectively trapped, heating the coolant contained within the tubes. The tubes are often composed of copper, with the backplate coated black to assist absorb solar radiation. Solar collectors are often insulated to prevent heat loss.

I. Types of solar collector:

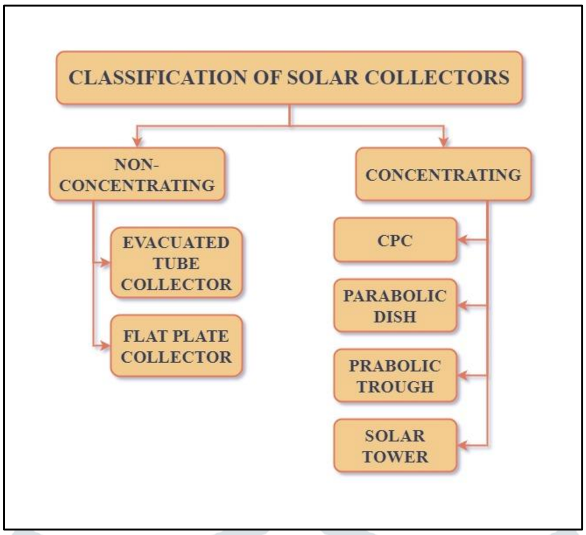

Fig 1. Classification of Solar Collectors

Non-concentrating collector-
They transport heat to a working fluid and retain heat using standard insulating materials like foam or fiberglass. Flat plate collector FPCs are often used in residential settings because of their ability to supply thermal energy for water and space heating [3]. However, large heat losses preclude these devices from running efficiently over 100 degrees Celsius.

Flat plate collector-Flat plate solar collectors are the most common type of non-concentrating solar collectors. The most common component of this form of solar collector is a series of vertically aligned metal tubes that convey cold water in parallel.[4] Heat loss is frequently reduced due to the greenhouse effect. The core of this form of thermal solar collector is a series of vertically aligned metal tubes that convey cold water in parallel. A horizontal pipe at the bottom connects the pipes to the cold-water intake, while another identical pipe at the top connects to the outflow. There is a cover at the top to protect the tubes. It is often double glass with an insulating layer at the bottom. This form of solar energy collector is utilized in low-temperature installations (usually below 79 degrees Celsius).[5]

Evacuated tube collectors (ETC)- Due to condensation moisture on flat plates, they were not on terms to perform precisely. So, the Evacuated Tube Collectors were introduced. Solar collectors are made of a heat pipe within a vacuum-sealed tube.[6] The vacuum enclosure decreases convection and conduction losses, allowing the collectors to function at greater temperatures than flat plate collectors. The sealed copper pipe is connected to a black copper fin that fills the tube (absorber plate). At the top of each tube, a metal tip is joined to the sealed pipe (condenser). The heat pipe evaporates and condenses a tiny amount of fluid, such as methanol. Solar heat evaporates the liquid, which then travels to a heat sink to condense and release latent heat. The accumulated fluid returns to the solar collector, where the process is repeated. To mount these tubes, place the metal tips into a heat exchanger (manifold). Water or glycol circulates across the manifold, collecting heat from the tubes. The heated liquid passes via a heat exchanger and transfers its heat to a process or water in a solar storage tank.

Concentrating solar collectors-
As name itself defines that solar beams were concentrated to a small area. A concentrating collector captures solar energy with high intensity using optical equipment such as reflectors or refractors.[7] It is a modified form of a flat plate collector with a reflecting or refracting surface (known as a concentrator) placed between the solar radiation and absorber. These collectors may considerably boost radiation intensity from low to high levels, sometimes by up to 10,000 times. They direct solar light from a vast region into a smaller receiver or absorber. This concentration of energy allows fluids to be heated to temperatures of 500 °C or even higher.[8]

Compound Parabolic Concentrator-
Compound Parabolic Concentrator (CPC) solar collectors are cutting-edge apparatuses intended to effectively gather and focus sunlight for a range of uses, such as solar photovoltaic (PV) systems and solar thermal energy conversion. A thorough explanation of CPC solar collectors is provided below:
Compound parabolic reflectors give CPC solar collectors its distinctive shape. Two or more parabolic sections are connected together to form a continuous shape to form these reflectors. This design's main goal is to effectively gather and reroute sunlight onto a chosen focal point or receiver.
Sunlight may be captured by CPC collectors over a broad range of incidence angles because to their compound parabolic form. CPC collectors may efficiently collect diffuse and off-axis sunlight as well, in contrast to conventional parabolic reflectors, which are best suited for direct sunlight alone. Because of its adaptability, the collector performs better in a variety of weather and solar angles
across the day.
CPC collector’s form lowers optical losses including reflection and scattering, which helps them achieve high optical potential. With this design, sunlight collecting is maximized and light ray dispersion is reduced, leading to improved energy capture and usage.

Parabolic Dish Concentrator-

A parabolic dish solar collector is a sort of concentrating solar power (CSP) system that directs sunlight into a single focal point, where it is then absorbed by a receiver using a dish-shaped reflector. The following is a thorough explanation of a parabolic dish solar collector:

A large, curved dish-shaped reflector composed of reflecting material, such metal or glass, makes up the parabolic dish solar collector. The paraboloid-shaped reflector concentrates incoming sunlight onto a single focal point with its curved surface. The collector's ability to focus sunlight across a limited region results in a notable increase in the intensity of solar radiation. The dish reflector's parabolic form makes sure that light falling on its surface is reflected in the direction of the focal point. Sunlight is concentrated and focused onto the receiver at the focal point as it hits the reflector. When compared to non-concentrating solar collectors, the temperature at the receiver rises noticeably because of this concentrated sunlight.

Parabolic Solar Trough Concentrator- Parabolic through may generate heat at temperatures up to 400°C. This collector consists of a parabolic mirror and a metal black tube coated with a glass tube is used to decrease heat loss.[10]

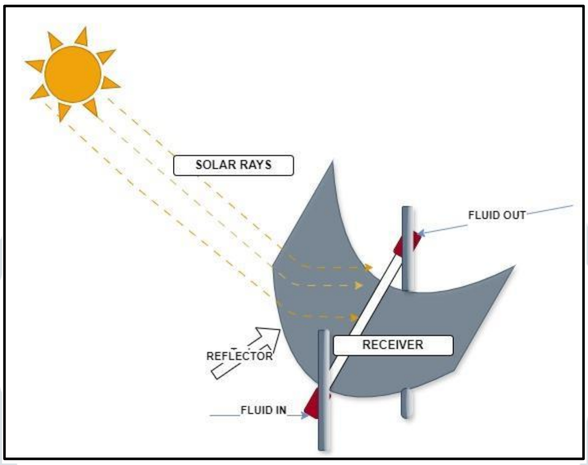

Fig 2. Parabolic Solar Trough Concentrator

The tube extending along the mirror's focus line depicts this type of solar collector. When the parabola is directed towards the sun, the reflector reflects parallel rays onto the receiving tube. Using just one axis is adequate. Long collector modules are commonly used for sun tracking. The collector may be oriented either east-west to follow the sun from north to south or north-south to track it from east to west. During the year, collectors in the south-north direction gather more energy, whereas collectors in the west-east direction are more effective during the summer months.[11]

Solar Tower Concentrator-

A solar tower is a sort of concentrating solar power (CSP) technology that uses a field of mirrors called heliostats to focus sunlight onto a central receiver at the top of a tower. It is also referred to as a solar power tower or a central receiver system. The following is a thorough explanation of a solar tower system:

Heliostats, or enormous fields of flat mirrors installed atop tracking devices to follow the sun's movement during the day, make up a solar tower system. The main purpose of the heliostats, which are positioned around a central tower in a circular or semi-circular design, is to focus and reflect sunlight onto the central receiver. To reflect sunlight onto the central receiver located at the top of the tower, each heliostat within the mirror field is separately controlled. The heliostats focus sunlight onto a tiny region at the receiver by varying the mirrors' angles, greatly boosting the solar radiation's intensity.

A central receiver is positioned at the summit of the tower to take in the concentrated solar energy coming from the heliostats. Depending on the exact design of the system, the receiver might be made up of a boiler or a number of heat exchanger tubes filled with a heat transfer fluid, or it could be a heat-absorbing surface. High-temperature steam is produced within the receiver as a result of the working fluid being heated by focused sunlight. The concentrated solar energy is absorbed by the working fluid in the central receiver, which is usually a high-temperature heat transfer fluid like liquid sodium, melted salt, or pressured water. After that, the heated fluid is sent via a closed-loop system to deliver thermal energy to a steam turbine or other power generating device.

II. Solar Tracking-

These days, the most prevalent applications of solar cells involve collecting solar energy and using it for various purposes such as battery storage, water heating, conveyance, etc. [12] The orientation of the sun varies according to the time of both the day and the season. Thus, in order to obtain solar radiation at its maximum where the sun is located solar panels must also be adjusted appropriately. Trackers are necessary for optimal effectiveness [13].

When we adjust the solar panel's angle in relation to the sun's angles on a regular basis, its potential rises. Solar tracking can contribute significantly to an increase in the output of electricity. Therefore, in large solar plants, the application of solar tracking devices is very important.[14]

Throughout the day and the year, the sun's position varies. Accordingly, there are two kinds of solar trackers depending on the tracking method.[15]

1) Single-Axis Solar Tracking Device

2) Solar Tracker with Dual Axis.

Single Axis Solar tracking device - [16] Single axis tracking systems can only rotate solar panels around one axis. Tracking can be done along either the North-South or East-West axes. The solar panel rotates about the East-West axis to track the sun periodically. The solar panel rotates about the North-South axis for continuous tracking.

Double Axis Solar Tracking Device- To collect more solar energy, the dual-axis tracking device follows the sun. The dual-axis tracking device is divided into two types in accordance with the type of axis: polar-axis tracking and altitude-azimuth tracking. Spinning-elevation tracking is a different acronym for polar-axis tracking.[17]

Advantages- after going through all the details about the solar collectors, here we have come to the summarization of advantages of this equipment.

- The main of all other advantages is that a solar collector uses unlimited sunlight to generate output work. And all this is done without harming the environment.
- It will require minimum mechanical or electrical equipment to run.
- It is affordable even for single household power generation.
- Easy to access and easy to run.
- Long life of materials and low environmental waste.
- Low cost including raw material either for household requirements or for industrial work.
- Reduce consumption of fossil fuels.

III. Conclusion

From the age of rock to the age of advancement, we have come across a drastic advancement. Solar collectors are one of them. The world is stepping towards environmentally friendly products. As they already know, fossil fuels are on the edge of extinction.
So, the use of solar collectors is an important step towards the environment, as are the other advantages that solar collectors lead to.

The potential and adaptability of solar collectors in a range of applications, including power production, desalination, air conditioning, refrigeration, and industrial heating, are highlighted in the analyzation. It offers a thorough grasp of the technology and its possibilities by examining several solar collector forms, such as parabolic troughs and dishes, as well as flat plate and concentrating collectors.

Additionally, the talk about solar tracking highlights how crucial it is to align solar panels optimally in order to optimize energy output and raise the overall potential of solar systems.

All things considered, the analyzation offers insightful information on the state of solar thermal applications today and is a useful tool for scholars and practitioners who want to learn more about and progress solar energy use. Its emphasis on environmentally friendly and sustainable energy solutions, the research aligns with the global imperative to mitigate climate change and transition towards a cleaner, greener future.

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