

A CASE STUDY AND RESEARCH ON THE SOLAR COLLECTOR

Avdhesh Kumar, Amit Kumar, Arslan Faridi, Dr. Ravindra Singh Shekhawat

Department of Mechanical Engineering, Arya Institute of Engineering and
Technology, Jaipur, India^{1, 2, 3, 4}

¹avdheshbtd@gmail.com

²amitsinu6@gmail.com

³arslanfaridi3754@gmail.com

⁴2016rmt9018@mnit.ac.in

Abstract— Solar collectors with flat plates are tools that are used to harvest solar thermal energy for uses in industry such as heating water and other surface. Level plate authorities are famous for low and medium warming applications and there are going through steady improvement regarding size decrease and upgraded productivity. This paper provides an overview of the various ways that flat late collectors can be made more effective. This paper discusses the effects of using nanofluids as a heat transfer fluid, changing the design of absorber plates to better capture radiation, ways to reduce heat loss, using polymer, using mini channels for fluid flow, using PCM (phase changing materials) to provide heat at night without a tank, and using enhancement devices like inserts and reflector. Along with the development methodology, a brief overview of the various methods used to analyze the effects and designs has also been provided. CFD models and some analytical studies have also been mentioned In addition, the recommendations for future research on heat transfer from solar flat plate collectors is the subject of this review paper.

Keywords— Solar collector, Nanofluids, Concentrating, Phase Changing Materials.

1. INTRODUCTION

The solar collector is a system that collect solar radiation and convert it into thermal or electrical energy that can be used. Many solar energy systems, which use the power of the sun to produce electricity, heat water, or heat buildings, depend on solar collectors as a key component.

Solar collectors come in two major variations: concentrator collectors and flat-plate collectors. Flat-plate collectors are the most common type, consisting of a flat, insulated box with a dark-colored absorber plate that is covered with a transparent glazing. Sunlight passes through the glazing and is absorbed by the plate, which then heats up and transfers the heat to a fluid (usually water or air) that circulates through the collector.

Concentrator collectors, on the other hand, use mirrors or lenses to concentrate sunlight onto a smaller area, which increases the amount of solar energy that can be captured. Concentrator collectors can be used for both thermal and photovoltaic (PV) applications, and they are often used in large-scale solar power plants.

Overall, solar collectors are an important technology for harnessing the abundant energy of the sun and reducing our dependence on fossil fuels.

2. SOLAR COLLECTOR TYPES

Solar collectors come in two main different types: concentrator collectors and flat-plate collectors.

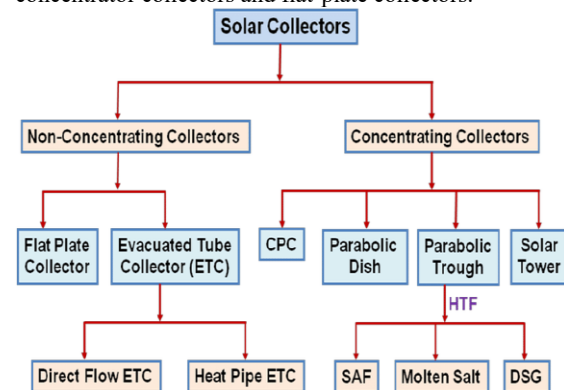


Fig.1 Non Concentrating Collector

A non-concentration collector, also known as a flat-plate collector, is a type of solar thermal collector used to harness solar energy for heating applications. It is one of the most common and widely used solar collector designs. The non-concentration collector consists of a flat, rectangular panel that is usually made of metal, such as copper or aluminum. The panel is covered with a transparent material, such as glass or plastic, which allows sunlight to pass through and traps the solar energy inside. Inside the collector, there is a network of tubes or channels that carry a heat transfer fluid, such as water or antifreeze. When sunlight strikes the collector, the absorbed solar energy heats up the fluid flowing through the tubes. This heated fluid can then be used for various applications, such as space heating, water heating, or even electricity generation through a heat exchanger or a power cycle. Non-concentration collectors are called so because they do not use any optical elements, such as mirrors or lenses, to focus or concentrate sunlight onto a smaller area. Instead,

they rely on the large surface area of the flat panel to absorb as much sunlight as possible.

Compared to concentration collectors, non-concentration collectors have a simpler design and are typically less expensive to manufacture. However, they are generally less efficient in converting sunlight into usable heat energy. Their performance is affected by factors such as solar radiation levels, ambient temperature, and the angle at which the collector is installed.

Non-concentration collectors are commonly used in residential and commercial solar water heating systems, where they provide a cost-effective solution for heating water using solar energy. They are also used in some space heating applications and in certain industrial processes that require low to medium temperature heat.

2.1.1 Flat-Plate Collectors:



Fig. 2 Flat Plate Collector

The most common type of solar collector, flat-plate collectors are often used in homes as well as small-scale commercial applications. They are constructed from up of a flat, insulated box with clear glass covering a dark-colored absorber plate. A fluid (often water or air) that flows through the collector is heated when sunlight enters through the glazing and is absorbed by the plate. PV and thermal applications may each make use of flat-plate collectors.

2.1.2 Evacuated tube collector:

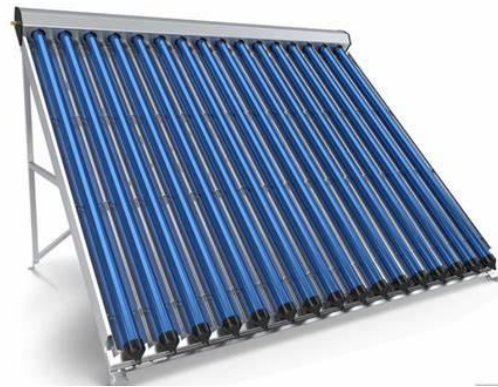


Fig. 3 Evacuated Plate Collector

An evacuated tube collector is a type of solar thermal collector used for harnessing solar energy. It is designed to maximize the absorption of solar radiation and minimize heat loss, making it more efficient than non-concentration collectors such as flat-plate collectors.

The evacuated tube collector consists of a series of parallel, transparent glass tubes that are connected to a header pipe at the top and bottom. Each glass tube contains an absorber tube made of metal, usually copper, which is coated with a selective coating to enhance solar absorption.

The air is evacuated from the space between the outer glass tube and the absorber tube, creating a vacuum. This vacuum acts as an excellent insulator, significantly reducing heat loss through conduction and convection. It mimics the insulating properties of a thermos bottle, allowing the collector to maintain high temperatures even in cold or windy conditions.

When sunlight strikes the collector, the selective coating on the absorber tube absorbs the solar radiation and converts it into heat. The heat is then transferred to the fluid flowing through the absorber tube. The fluid, typically a heat transfer fluid such as water or antifreeze, absorbs the heat and carries it to a heat exchanger or storage tank, where it can be used for various applications like space heating, water heating, or industrial processes.

The evacuated tube design offers several advantages over other collector types. It provides high thermal efficiency due to the vacuum insulation, allowing it to reach higher temperatures and operate in colder climates. The individual tubes also allow for modularity, enabling easy replacement or repair if one tube becomes damaged. Additionally, the design allows the collector to track the sun's movement throughout the day, maximizing solar exposure.

Evacuated tube collectors are commonly used in residential, commercial, and industrial applications where high-temperature heat is required. They are particularly effective for colder climates and areas with less direct sunlight. Due to their efficiency, they are suitable for heating applications that demand higher temperatures or where space is limited.

2.2 Concentrating Collectors:



Fig. 4 Concentrating collector

Concentrator collectors use mirrors or lenses to concentrate sunlight onto a smaller area, which increases the amount of solar energy that can be captured. Concentrator collectors can be used for both thermal and PV applications, and they are often used in large-scale solar power plants. There are three main types of concentrator collectors:

2.2.1 Parabolic Trough Collectors:

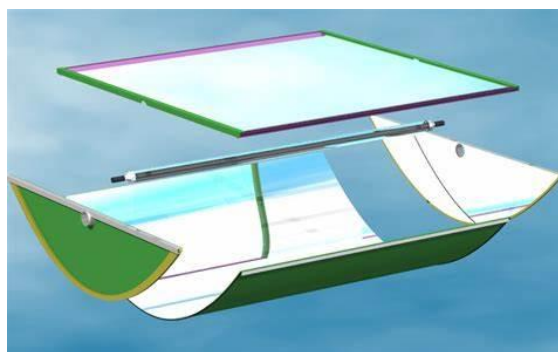


Fig. 5 Parabolic Trough collector

Sunlight is directed onto a receiver tube that runs through the center of the collector by use of parabolic-shaped reflectors in a device known as a parabolic trough collector. A heat-transfer component, such as oil, is found in the receiver tube and absorbs concentrated sunlight before passing the heat to a power plant's steam cycle to generate electricity.

2.2.2 Collectors of dishes:

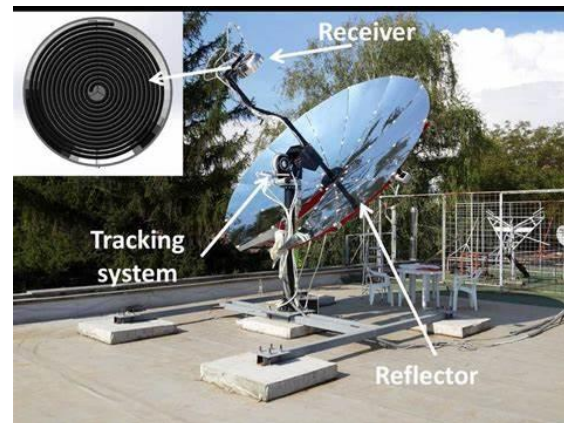


Fig. 5 Dish collector

Dish collectors direct sunlight onto a receiver at the focal point of the dish using parabolic-shaped mirrors. In order to generate electricity, the concentrated sunlight passes to a power plant's steam cycle using a heat-transfer fluid inside the receiver.

2.2.3 Fresnel Reflectors:



Fig. 6 Fresnel collector

Fresnel reflectors use flat mirrors arranged in a series of segments to concentrate sunlight onto a receiver located at the focal point of the collector. The receiver contains a heat-transfer fluid that absorbs the concentrated sunlight and transfers the heat to a power plant's steam cycle to generate electricity.

Overall, both flat-plate and concentrator collectors are important technologies for harnessing the energy of the sun and reducing our dependence on fossil fuels.

3. THE PROS AND CONS OF A SOLAR COLLECTOR

3.1 Solar collector advantages:

As compared to conventional fossil fuel-based energy systems, solar collectors provide a number of advantages:

Solar energy is a renewable energy source, which implies there will never be a shortage of it. Fossil fuels, on the other hand, are limited resources that will eventually run out.

- **Cost Savings:**

Once installed, solar collectors can generate free energy for many years, which can result in significant cost savings on energy bills over time.

- **Low Maintenance:**

Compared with conventional energy systems, solar collectors require minimal maintenance because they have no moving parts.

- **Environmentally Friendly:**

Unlike with traditional energy systems, solar energy systems are cleaner and more friendly to the environment because they don't generate any greenhouse gases or other pollutants.

- **Versatility:**

Solar collectors may be utilised for a wide range of tasks, including producing energy, heating water, and heating buildings.

- Solar energy can improve energy security by lowering reliance on imported oil and other fossil fuels. Overall, when people search for ways to reduce their carbon footprint and save money on energy costs, solar collectors provide a clean, sustainable, and affordable alternative to create electrical power.

3.2 Drawbacks of solar collector:

While solar collectors convey many advantages, there are also some drawbacks to take into account:

- **Initial Cost:**

For some persons and institutions, the initial cost of installing a solar collector system might be excessive.

- **Dependence on sunshine:**

Since solar collectors require direct sunshine to generate energy, dark or cloudy conditions could affect their performance.

- **Electricity Storage:**

Because solar collectors only produce electricity when the sun is out, energy storage devices like batteries are required to supply energy when the sun is not out.

- **Land use:**

It may be challenging to acquire sufficient space for large-scale solar power set up in areas with a lack of available land. It can be challenging in spaces where land is scarce.

- **Environmental Impact:**

Although solar energy is a cleaner and greener energy source than fossil fuels, the production of solar collectors can still have some adverse impacts on the environment, especially if the manufacturing process is not eco-friendly. While solar collectors offer numerous advantages overall, there are certain drawbacks and difficulties that need to be resolved as we seek to make the switch to a cleaner, more sustainable energy future.

4. SOLAR COLLECTOR APPLICATION

There are multiple applications for solar collectors, including the following:

Heating Water:

Homes, organizations, and other frameworks may use solar collectors to heat their water. One of the most common applications for solar collectors is this.

Space Heating: Buildings inside air may be warmed using solar collectors, which could decrease their reliance on traditional heating systems.

Electricity Generation:

Solar collectors can be used to generate electricity through photovoltaic (PV) technology or through concentrating solar power (CSP) technology.

Industrial Applications:

Solar collectors can be used in industrial processes, such as drying crops or heating water for manufacturing processes.

Transportation:

Solar collectors can be used to power electric vehicles or to generate hydrogen for fuel cell vehicles.

Desalination: Solar collectors can be used to desalinate seawater, providing a source of fresh water in areas where water is scarce.

Agriculture:

Solar collectors can be used to power irrigation systems, as well as to provide heat for greenhouses and other agricultural applications.

Overall, solar collectors have a wide range of applications and are a versatile technology that can be used in many different ways to generate clean, renewable energy.

5. RECENT DEVELOPMENT

Solar collector technology has continued to develop rapidly in recent years, with many exciting new developments in the field. Here are a few examples:

High-Efficiency Solar Cells: Researchers are continually working to develop more efficient solar cells, which can capture more sunlight and generate more electricity. New materials, such as perovskite, are showing promise for achieving higher efficiency.

Concentrating Solar Power (CSP): Concentrating solar power technology, which uses mirrors or lenses to focus sunlight onto a small area, is becoming more efficient and cost-effective, making it an increasingly popular option for large-scale solar power plants.

Thermal Storage:

One of the challenges of solar collectors is that they only generate energy when the sun is shining. However, new thermal storage technologies are being developed that can store heat generated by solar collectors and release it later, providing a more reliable source of energy.

Building-Integrated Photovoltaics (BIPV):

BIPV technology allows solar cells to be integrated into building materials, such as roof tiles or windows, making it possible for buildings to generate their own electricity.

Floating Solar Panels:

Floating solar panels are a new development that allows solar collectors to be installed on bodies of water, such as

reservoirs or lakes, providing a new source of renewable energy without taking up land.

Overall, there are many exciting developments in solar collector technology, and the field is expected to continue to grow and evolve as we work to transition to a more sustainable energy future.

6. FUTURE

As we seek to shift away from fossil fuels and towards more sustainable energy sources, solar collectors are anticipated to play an increasingly significant part in the future of energy generation. Future applications for solar collectors include the following:

Large-Scale Solar Power Plants:

As solar collector technology becomes more efficient and cost-effective, we can expect to see more large-scale solar power plants being built, providing a significant source of renewable energy to power homes and businesses.

Building-Integrated Photovoltaics (BIPV):

BIPV technology is likely to become more common in the future, with solar cells being integrated into building materials, such as roof tiles and windows, making it possible for buildings to generate their own electricity.

Electric Vehicles:

Solar collectors could be used to power electric vehicles, either through direct charging or through the production of hydrogen for fuel cell vehicles.

Space-Based Solar Power:

Some researchers are exploring the idea of using solar collectors in space to generate electricity, which could then be transmitted back to Earth using microwaves or other technologies.

Desalination:

As water scarcity becomes an increasing concern, solar collectors could be used to power desalination plants, providing a source of fresh water in areas where water is scarce.

Overall, solar collector technology is likely to play a significant role in the future of energy generation, and we can expect to see continued developments in the field as we work towards a more sustainable energy future.

7. CONCLUSION

In conclusion, solar collectors are an important and rapidly developing technology with a wide range of applications. They have the potential to significantly reduce our reliance on fossil fuels, mitigate the impacts of climate change, improve access to energy, and stimulate economic development. While solar collectors have some disadvantages, such as their intermittency and upfront costs, continued advancements in technology are making them more efficient, cost-effective, and accessible. With ongoing investment and research, solar collectors have the potential to become a key component of our energy system, helping to create a more sustainable and environmentally responsible future.

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