Base on solid-works design of compact high efficient solar water heating System.

RAMCY SAAH STUBBLEFIELD (stubblefieldramcy8@gmail.com)
Changchun University of Science and Technology

Article

Keywords: Solar, Water Heater, Solar Water, Heating system

Posted Date: April 11th, 2023

DOI: https://doi.org/10.21203/rs.3.rs-2756799/v2

Abstract

A solar water heating system is a technology that uses the sun's energy to heat water for domestic or industrial purposes. The system consists of a solar collector, a storage tank, and a circulation pump. The solar collector is made up of an array of solar panels, which absorb the sun's energy and transfer it to the water flowing through them. The heated water is then stored in the tank for later use.

A solar water heater is a type of heating system that uses solar energy from the sun to heat water for domestic, industrial, or commercial use. It typically consists of a solar collector panel or array, a storage tank, and plumbing or circulation systems. The solar collector panel absorbs the energy from the sun and transfers it to the water in the storage tank. The heated water can then be used for various purposes, such as showering, washing, or space heating.[1,2]

A solar heating system, on the other hand, is a more general term that refers to any type of heating system that utilizes solar energy. This can include solar water heaters, but it can also include other systems, such as solar space heaters, solar air heating systems, or solar-assisted heat pumps. Solar heating systems can be used in residential, commercial, or industrial settings and can be integrated with existing heating systems to provide a renewable energy source and reduce reliance on fossil fuels.[1]

Solar water heating systems are becoming increasingly popular as they provide an efficient and cost-effective way of heating water. They are particularly useful in areas with abundant sunshine, where they can reduce the reliance on fossil fuels and lower carbon emissions. They are also well-suited for remote or off-grid locations where access to electricity or gas is limited or costly.

The performance of a solar water heating system depends on various factors, including the size and type of collector, the quality of insulation, and the climate conditions. Proper maintenance and regular cleaning of the collector and storage tank are essential to ensure optimal performance and longevity of the system.

Introduction

A solar water heating system is a technology that utilizes energy from the sun to heat water for domestic or industrial purposes. It consists of a solar collector, a heat exchanger, a storage tank, and a circulation pump.

The solar collector is typically mounted on a roof or a nearby structure and is designed to absorb solar radiation and convert it into heat. The collector is usually made of metal, glass, or plastic and has tubes or channels through which water flows.

The heat exchanger is used to transfer the heat from the solar collector to the water in the storage tank. It can be either a simple coil of pipe or a more complex system that uses a heat exchanger to transfer the

heat. The storage tank is where the hot water is stored for later use. It is usually insulated to reduce heat loss and can be made of a variety of materials, including glass-lined steel, copper, or plastic.

The circulation pump is used to move the water from the storage tank to the collector and back again. This is done to ensure that the water in the tank remains hot and that it is circulated through the system properly.

The Sun produces a tremendous amount of energy that could potentially meet the energy requirements of our planet, but extracting energy from it has been difficult compared to fossil fuels or nuclear power. Solar energy has been effective in producing electricity and heat, and solar hot water systems are popular due to their low cost and ease of maintenance. The goal of a thesis on this topic is to create an efficient hot water system that utilizes natural resources and reduces electricity consumption. One way to increase efficiency is to provide proper insulation to reduce heat loss.[3]

The use of solar energy for water heating is an effective and natural technology that can help reduce reliance on fossil fuels. Solar water heaters can be active or passive, and their performance depends on the availability of solar energy and the temperature of incoming water. [2]Photovoltaic thermal technology combines PV cells and thermal collectors to generate both thermal and electrical energy. Using Al2O3 and MWCNT water Nano fluids as working fluids can significantly increase the efficiency of flat plate solar collectors. Hybrid domestic hot water systems that combine with thermo- electric air conditioners can also be effective. However, the thermal efficiency of solar water heaters may be reduced in winter due to lower temperatures and less solar radiation.[3]

Solar water heating systems are a popular choice for household and swimming pool water heating because they are environmentally friendly and use energy from the sun. There are two types of solar collectors, with evacuated tube collectors being the most efficient. Researchers have focused on improving and measuring heat transfer losses in both types of collectors. The cost of solar water heaters has decreased in the last ten years, with prices ranging from $800 to $10,000. The paper aims to investigate the efficiency and cost analysis of solar water heaters.[3]

The world is facing harmful effects from conventional energy sources and an increasing demand for energy due to population growth. Therefore, renewable energy sources have become a priority, particularly in fields such as solar water heating. There have been many innovations in the design of solar water heaters, and this study focuses on a modified design of a flat plate collector for water heating. This research covers four countries mainly Liberia, China, Sweden and Malaysia, looking at their climates, and suggests that the modified design could be successful in improving efficiency and cost optimization. [4]

Solar water heating is a technology of capturing the energy from the sun’s radiation for the purpose of raising the temperature of water from water supply temperature to the desired higher temperature depending on the use. There are many views and discussions on the questions of thermal efficiency of

solar water heaters and their associated cost, especially different customers/users want to replace their existing conventional water heating energy by solar water heating systems. In this paper, a deep investigation has been accomplished to determine thermal efficiency and cost analysis of solar water heater which can be used in Liberia specifically and other parts of the world. The humid, tropical climate in Liberia shows relatively constant temperatures throughout the year, around the average of 27° C (81° F), hardly ever outside the range of 20° C (68° F) to 36° C (97° F). In Liberia, monthly solar radiation on horizontal surface ranges from about 4 kWh/m^2/day during the rainy season in June, July, and August to 6 kWh/m^2/day during the height of dry season in February and March. This high and consistent potential for solar energy across the country adds to an average level of 1,712 kWh/m2/year, which could generate 1,400 to 1,500 kWh/kWp.[6]

According to the World Bank Fact book (CIA) electricity consumption is about 39 million kWh (2016 est.) Based on a 2014 household survey, only 4.5% of Liberian Electricity Cooperation (LEC) power. 4.9% used community generator current,4.4% have their own generator,3.9% used vehicles batteries,0.8% used other sources of electricity.[7]

81.3% have no access to electricity. LEC accounts for roughly 70 million kWh of output (2016 est.) 9.1% of the population have access to electricity,16.8% of Urban population, and 1.7% of Rural population (World Bank 2014 est.)

Energy consumption in Liberia is dominated by biomass with a shear of more than 80% of the used primary sources. Most important is woody biomass used for domestic cooking and heating. In 2004, it was estimated that over 95% of its population depended of firewood and charcoal for cooking and heating needs and palm oil for lighting. Most recent census (2008 data, published in 2009 by The World Bank) shows that 70% of the urban population used charcoal for cooking and 5% of the rural population; 91% of the rural population used firewood for cooking and 21% of the urban population. In Monrovia, the percentage of households using charcoal is even higher, 85%. Around 2% of the population have access to clean fuels and technologies for cooking etc. (World Bank, 2014). With this my research which is aimed at providing solutions to the many electric energy problems in Liberia and other parts of the world, I hope to have this my model which is environment friendly and less cost effective to meet up with such demands of Liberia and the World at large. Similarly, this modified design of the solar water heater is expected to achieve around 5% more thermal efficiency than the previous designs. The thermal efficiency has been found to decrease rapidly when the ambient temperature increases. [2]

Since the Third Industrial Revolution, human society in economy and technology has developed unprecedentedly but a series of problems have arisen at the same time. One main problem is energy shortage due to the conventional energy structure which relies on large supply of fossil fuels. As shown in Fig.1 the world energy consumption by fuel from the year 1870 to 2030, fossil fuels, as well known as Coal, Oil and Gas, are the dominant energy sources till today.[8]

The world's primary energy consumption is expected to increase by 1.6% annually by 2030, and total energy consumption is predicted to double by 2050 compared to 2005. However, the world's conventional fossil fuel reserves are limited and cannot meet the increasing energy demand. Excessive consumption of fossil fuels also leads to long-term environmental problems such as global warming. Therefore, the conversion to renewable energy, particularly solar energy, is essential. Despite only a small fraction of solar radiation reaching the Earth's surface, solar power is abundant, inexhaustible, and clean.[6]

The power from the sun intercepted by the Earth is many times larger than the present rate of all energy consumption, and solar radiation is the principal source of much renewable energy. Solar thermal technologies are regarded as the most economical way of utilizing solar energy, and their history can be traced back to ancient times. The manufacture of solar water heaters began in the early 60s and has developed into a largely mature market worldwide. Solar collector technologies are necessary to concentrate solar radiation for utilization.[10]

Solar collectors are essential components in solar energy systems that absorb solar radiation and convert it into heat to be transferred to a working fluid. They can be classified based on various criteria, with flat plate collectors and evacuated tube collectors being the most widely used.

Flat plate collectors are simple, cost-effective, and can collect as much solar energy as possible, while evacuated tube collectors are ideal for high-temperature operation and have low heat losses and high durability. Both types of collectors are used in various applications, such as solar water heating, solar space heating and cooling, solar reAt the end of 2012, the global solar hot water capacity was approximately 282 GWth, with glazed water collectors accounting for 255 GWth.

China and Europe have the highest market share for all types of collectors, and solar hot water collectors are used in over 56 countries for various applications. China is the biggest producer and seller of solar water heaters and has become a leader in the solar thermal market. The paper discusses the condition of SWHs market in China, including the types of SWHs, their prices, and why evacuated SWHs are popular. The paper also examines the Swedish market and its policies in renewable energy, which can help to understand the impacts and trends of the whole European market.frigeration, and solar thermal power systems.[9]

Problem Formulation

This research focuses on the design of a modified solar water heater system using a flat plate collector that achieves higher thermal efficiency and lower costs. The research is aimed at providing sustainable and renewable energy solutions to countries such as Liberia, China, Sweden, and Malaysia that have faced challenges in meeting their energy demands. The modified design is expected to achieve 5% more thermal efficiency than previous designs, with a low daily collector heat loss and a calculated payback period of 5 years, making it economically advantageous for residential buildings.Solar water heating is the process of using solar radiation to increase water temperature. The efficiency and cost of this

technology are often debated, particularly among those looking to replace traditional water heating methods.

Methodology

This research followed the following methodology:

- Literature Review: Conducting a comprehensive review of existing literature related to machining solar energy.
- Designing of our models using solid-works 3D software
- Comprehensive analysis of solar energy usage in few countries.

2.1 Objectives

The objectives of this design are to: 1) increase the efficiency level of a solar hot water system by reducing heat loss and using renewable energy, 2) work on insulation to minimize temperature drop overnight, 3) increase system efficiency to utilize it fully,4)to work on insulation at variable time, temperature, and solar radiation, 6)to make a meaningful difference to the growth and development of Liberia and the world's energy demands and economies.

10) Identify potential technology pathways and cost/performance targets that must be met to enable SWH systems to achieve large energy savings.

Discussion

- **How to increase the efficiency level of a solar hot water system by reducing heat loss and using renewable energy?**

There are several ways to increase the efficiency level of a solar hot water system by reducing heat loss and using renewable energy. Here are some of them:

- Increase insulation: Insulate the pipes, storage tank, and solar collector to reduce heat loss. This can be done by adding additional insulation material such as foam or fiberglass to these components.

- Use a larger collector: A larger collector will allow more solar energy to be absorbed, increasing the amount of heat produced. This can be achieved by adding more solar panels or using a larger solar collector.

- Use a heat ex-changer: A heat ex-changer can be used to transfer heat from the collector to the water in the storage tank more efficiently. This can increase the efficiency of the system by reducing heat loss.

- Use a timer: A timer can be used to ensure that the circulation pump only operates during the hours when the sun is shining. This reduces the amount of energy used by the pump and increases the efficiency of the system.
- Use renewable energy: To further reduce energy consumption, consider using renewable energy sources to power the circulation pump. This could include wind power, solar power, or hydro power.

- Reduce water usage: Reducing water usage can help to reduce the amount of energy needed to heat water. This can be achieved by using low-flow shower-heads, fixing leaky faucets, and taking shorter showers.

- **How to work on insulation to minimize temperature drop overnight?**

Insulation is a critical component of a solar hot water system that can significantly reduce heat loss and minimize temperature drop overnight. Here are some ways to work on insulation to achieve this:

- Insulate the pipes: The pipes that transport hot water from the collector to the storage tank should be insulated with foam insulation. This will help to minimize heat loss and reduce temperature drop overnight.

- Insulate the storage tank: The storage tank should be insulated with a thick layer of foam insulation. This will help to retain heat and minimize temperature drop overnight.

- Use a heat ex-changer: A heat ex-changer can be used to transfer heat from the collector to the storage tank more efficiently. This can reduce heat loss and minimize temperature drop overnight.

- Seal gaps and leaks: Any gaps or leaks in the insulation should be sealed to prevent air from entering and causing heat loss.

- Use reflective insulation: Reflective insulation can be used to reflect radiant heat back into the storage tank, reducing heat loss and minimizing temperature drop overnight.

- Consider adding a backup heating system: A backup heating system, such as an electric or gas water heater, can be used to maintain the temperature of the water in the storage tank overnight when there is insufficient sunlight to heat the water.

By working on insulation in these ways, you can minimize temperature drop overnight and ensure that your solar hot water system is operating as efficiently as possible.

- **How increase system efficiency of solar water heater to utilize it fully?**

To increase the system efficiency of a solar water heater and utilize it fully, there are several strategies that you can implement. Here are some of them:

- Ensure proper installation and maintenance: Proper installation and maintenance are critical to ensuring that your solar water heater operates efficiently. Regular maintenance can help to prevent problems such as leaks and can help to ensure that the system is operating at optimal efficiency.

- Use a high-efficiency solar collector: Using a high-efficiency solar collector will allow more solar energy to be absorbed, increasing the amount of heat produced and the overall efficiency of the system.

- Use a heat ex-changer: A heat ex-changer can be used to transfer heat from the collector to the water in the storage tank more efficiently. This can increase the efficiency of the system by reducing heat loss.

- Use a controller: A controller can be used to ensure that the circulation pump operates only when there is sufficient sunlight to heat the water. This can help to reduce energy consumption and increase the efficiency of the system.

- Consider adding a backup heating system: Adding a backup heating system, such as an electric or gas water heater, can help to ensure that you have hot water even when there is insufficient sunlight to heat the water. This can help to increase the overall efficiency of the system by ensuring that it is being used to its full potential.
- Consider adding a solar tracker: A solar tracker can be used to track the movement of the sun and adjust the position of the solar collector accordingly. This can help to maximize the amount of solar energy absorbed and increase the overall efficiency of the system.

By implementing these strategies, you can increase the system efficiency of your solar water heater and utilize it fully, which will not only save you money but also reduce your environmental impact.

- **How to work on insulation at variable time, temperature, and solar radiation?**

Working on insulation at variable time, temperature, and solar radiation in a solar water heating system requires a flexible approach. Here are some strategies you can use:

- Use different types of insulation: Different types of insulation materials have different properties that make them more or less suitable for certain conditions. For example, fiberglass insulation is better at reducing conductive heat transfer, while reflective insulation is better at reducing radiant heat transfer. Using a combination of different types of insulation can help to ensure that your system is well-insulated under different conditions.

- Use insulation with different thicknesses: Insulation thickness should be selected based on the expected temperature and solar radiation conditions. Thicker insulation is better at reducing heat transfer, so it may be more appropriate for colder or less sunny climates. Thinner insulation may be sufficient for warmer or sunnier climates.

- Use a thermal storage system: A thermal storage system can be used to store hot water for later use, reducing the need for heating during periods of low solar radiation or at night. Insulation should be applied to the storage tank to minimize heat loss and ensure that the stored water remains hot.

- Monitor and adjust insulation: Insulation should be monitored regularly to ensure that it is performing as expected. If there are significant changes in temperature or solar radiation, adjustments may need to be made to the insulation to maintain optimal performance.

- Use computer simulations: Computer simulations can be used to model the performance of a solar water heating system under different conditions. This can help to identify areas where insulation may need to be improved and guide decisions on insulation thickness and type.

By using a flexible approach and implementing these strategies, you can work on insulation in a solar water heating system under variable time, temperature, and solar radiation conditions. This can help to ensure that the system operates at optimal efficiency and reduces energy consumption.

- **How would solar energy make a meaningful difference to the growth and development of Liberia and the world's energy demands and economy?**

Solar energy has the potential to make a significant difference to the growth and development of Liberia and the world's energy demands and economies. Here are some ways in which solar energy can contribute:

- Reduced reliance on fossil fuels: Solar energy is a renewable energy source that does not produce greenhouse gas emissions. By reducing reliance on fossil fuels, solar energy can help to mitigate climate change and reduce the negative impacts of pollution on public health.

- Increased energy access: In Liberia and other developing countries, many people lack access to electricity. Solar energy can provide a reliable and cost-effective source of electricity that can be used

to power homes, businesses, and other critical infrastructure. This can improve quality of life and support economic development.

- Job creation: The growth of the solar energy industry can create jobs in manufacturing, installation, and maintenance. This can provide employment opportunities and support local economic development.

- Energy security: Solar energy can provide a source of energy that is not subject to price fluctuations or supply disruptions associated with fossil fuels. This can enhance energy security and reduce the risk of economic disruptions due to energy shortages.
- Cost savings: Solar energy has become increasingly cost-competitive with traditional sources of energy, such as coal and natural gas. By investing in solar energy, countries and businesses can reduce energy costs and improve their bottom line.

Overall, solar energy has the potential to contribute to sustainable development and economic growth while reducing the negative impacts of energy production on the environment and public health.

3.1.1 Description of the system

This system uses a 150 miters solar collector and a 300 liters storage tank to store water As shown in Fig.2&3 below. The optimum temperature for storing water in the tank has been analyzed, and the loss of temperature is noted. The system uses steel pipes coiled together and a metal plate with black paint to absorb solar rays, along with two reflective sheets to gather and reflect additional rays. The system heats up the pipes and water passing through them, which can be used through a third outlet. This efficient solar water heater saves over 99% energy and provides warm water instantly.

The solar hot water system has an operating temperature of the outlet water from the storage tank, and if it cannot meet the desired temperature, an electric water heater is used. The system is driven by a micro-controller and uses thermostat technology to reduce costs. PV systems require components such as solar modules, charge controller, battery, inverter, lightning protection, storage tank, and mounting frame. These components convert sunlight into electricity, regulate voltage and current, store electricity, convert DC power into AC power, protect equipment from lightning, and hold the PV solar collector. Below are designs of the solar battery, inverter and an arduino Uno3 sensor device.

Basically there are two types of solar thermal collectors that are used in such system: evacuated tube collector and flat plate collector. Efficiency per unit area of evacuated tube collectors at low temperature can exceed that of flat plate collectors and the difference in performance becomes more significant as the average 10 operating temperature increases.

Problem Solution

The objectives of this design are to: 1) increase the efficiency level of a solar hot water system by reducing heat loss and using renewable energy, 2) work on insulation to minimize temperature drop overnight, 3) increase system efficiency to utilize it fully, and 4) use different types of insulating material and measure irradiance with a pyrometer.5. to increase its efficiency level by reducing heat loss, 6)to work on insulation at variable time, temperature, and solar radiation, 7)to use different types of insulating material and measure its irradiance with a pyrometer, 8)to identify the operating optimum temperature, 9)to be environmentally friendly and widely used in residential buildings, 10)to meet economic demands, 11)to be easy to maintain with a simple design, and 12)to make a meaningful difference to the growth and development of Liberia and the world's energy demands and economies.

11. Identify potential technology pathways and cost/performance targets that must be met to enable SWH systems to achieve large energy savings.

Conclusion

Taken into considerations the existing situation into the energetically field, it is foreseeable that an alternative energy sources will become more and more charismatic and remarkable part played into this project to be achieve through the use of solar collector. It has been seen that the regions where the sun radiation is high, the performance of both collector and tank is also good.

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Figures

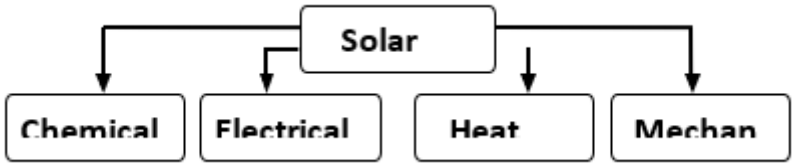

Figure 1

Conversion of solar radiation to other energy forms

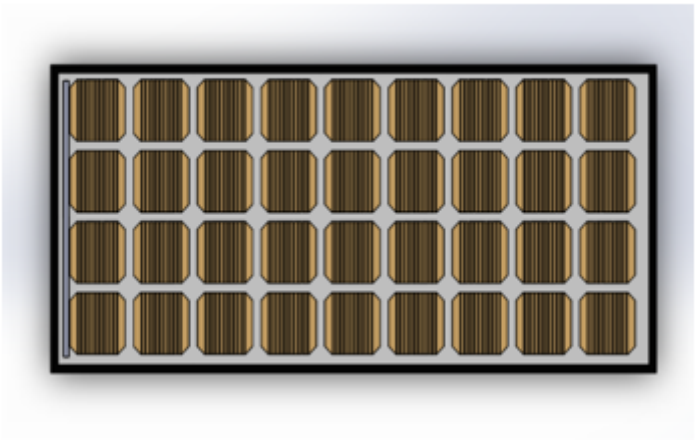

Figure 2

MODEL OF PV SOLAR PANEL

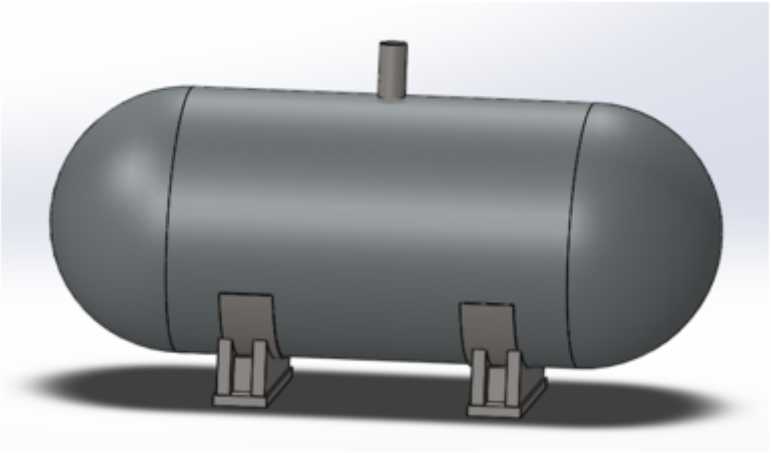

Figure 3

DESIGN OF THE WATER TANK

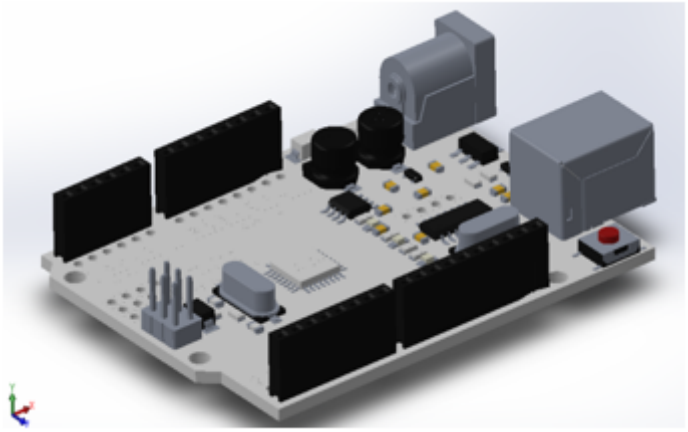

Figure 4

Arduino Uno3 sensor device.

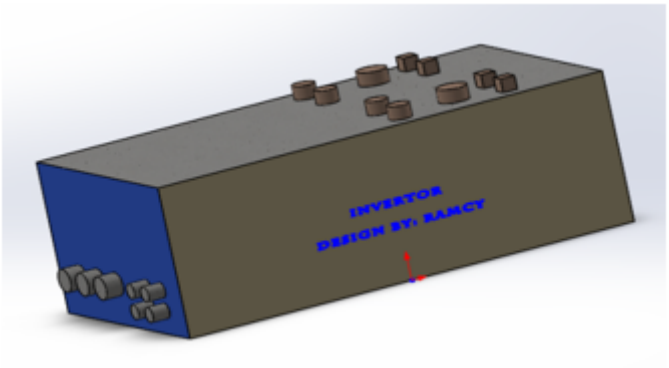

Figure 5

Design of Inverter