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COMPREHENSIVE ANALYSIS AND EVALUATION OF THE IMPACT OF VARIABLE RECEIVER ABSORBANCE ON ENERGY PRODUCTION IN PARABOLIC TROUGH SYSTEMS

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Abstract- In recent years, there has been a shift toward the production of solar thermal energy using parabolic trough systems. This shift can be attributed to the high efficiency and dependability of these systems. However, the height of the receiver that should be used in these systems in order to achieve maximum energy output is still a matter of debate. Within the scope of this study is an investigation into the connection that exists between the amount of energy produced and the receiver height within parabolic trough systems. In order to simulate the conditions that exist in the actual world and assess the amount of energy that can be generated by parabolic trough systems at a variety of receiver heights, simulations were run in controlled environments. Tests were performed at intervals of 0.25% on heights ranging from 25% to 100% of the parabolic trough's total percentage. According to the findings, the height of the receiver that should be used to achieve maximum energy production is dependent on a number of different parameters, including the geographic location of the system as well as the time of day. It was discovered that the optimal receiver height for attaining the maximum amount of energy output was, in most cases, higher in locations that received a greater amount of solar radiation. The findings offer helpful insights for the design and operation of parabolic trough systems for the generation of solar thermal energy. This can contribute to the development of solar energy systems that are more efficient and cost-effective.

Keywords: Parabolic Trough Systems, Receiver Height, Solar Thermal Energy.

1. INTRODUCTION

In Jordan, like in other parts of the world, there is a severe lack of available energy resources. This lack of energy resources is the most significant obstacle standing in the way of development and advancement. Jordan is dependent on traditional energy sources imported from neighboring countries and around the world in order to secure its energy supply. The proportion of Jordan's energy requirements that is met by imported energy exceeds 90 percent, which places significant financial, political, and other burdens on Jordan and its overall development. Jordan is one of the countries in the world that enjoys long hours of solar radiation and high radiation rates, which makes solar energy an ideal source to rely on in addition to wind energy, which is no less important. Recently, renewable energy has emerged as an important and reliable whole in securing Jordan's need for energy. This is especially true given that Jordan is one of the countries that enjoy long hours of solar radiation and high radiation rates. When it comes to solar energy in Jordan, all of these factors have combined to make Jordan one of the richest countries in terms of its sources of renewable energy [1-4].

Solar energy is a significant source of renewable energy that has the potential to revolutionize how we provide power to our homes, businesses, and communities. Solar energy, in contrast to fossil fuels, is clean, abundant, and broadly accessible [5]. It does not emit greenhouse gases or other pollutants that are hazardous to the environment and human health. Also, solar energy is getting more affordable, making it a feasible alternative for many households and companies. Solar energy can aid in reducing our reliance on fossil fuels and mitigating the effects of climate change [6-11].

The impact of solar radiation on Jordan's climate and energy profile is significant. Due to its location in the Middle East's sunny region, Jordan has a significant solar energy potential. The country receives an average of 3,000 hours of sunlight annually, making it a perfect location for the development of solar energy. Jordan is also one of the few countries in the area without large oil or gas reserves, which has prompted the government to make substantial investments in renewable energy [8, 9, 12-15].

The two primary categories of solar potential for Jordan are direct normal irradiance (DNI) and global horizontal irradiance (GHI). DNI is the quantity of direct solar radiation received, while GHI is the entire amount of radiation received from the sun, including both direct and diffuse radiation. The annual average DNI in Jordan ranges between 5.5 and 7.5 kWh/m^2, whereas the GHI ranges between 5.8 and 6.6 kWh/m^2 [16-21].

Concentrated solar power (CSP) is a sort of solar technology that employs mirrors or lenses to focus sunlight on a small area, thereby generating heat that may be utilized to generate electricity. CSP plants may create electricity even when the sun is not shining because they can store heat in molten salt or other substances [22, 23]. In regions with high direct sun radiation, CSP technology can be more efficient than typical photovoltaic solar panels, and it has the potential to replace fossil fuel-powered facilities, thereby lowering carbon emissions. CSP technology is, however, more costly to construct and operate than photovoltaic solar panels, which has prevented its broad adoption [24].

One of the most common types of concentrated solar power (CSP) technologies is the parabolic trough system. They employ parabolic-shaped mirrors to concentrate sunlight onto a pipe running along the parabola's focal line. This pipe contains a fluid, often oil or molten salt, which is heated by concentrated sunlight to generate steam, which is subsequently used to make electricity. It is possible to construct parabolic trough systems to store heat in a thermal energy storage system, allowing them to generate power even when the sun is not shining. The first commercial parabolic trough power plant was constructed in the 1980s, therefore the technology is mature and well-established. However, they are costly to construct and maintain, and their effectiveness is limited by the quality of the mirrors and the amount of available sunlight [25-27]. Parabolic trough system is a type of CSP technology that use parabolic reflectors to concentrate sunlight onto a heat-transfer fluid-filled receiving tube. The concentrated sunlight heats the fluid, which is then utilized to generate steam that drives a turbine to generate electricity. This process's effectiveness is contingent on a variety of variables, including the absorption qualities of the receiver tube [28, 29].

According to the findings of several studies, changes in receiver absorbance can have a sizeable bearing on the amount of energy that can be extracted from parabolic trough systems. According to the findings of a study that was carried out by the National Renewable Energy Laboratory (NREL), a drop of only 5% in receiver absorbance could lead to a reduction of between 5% and 6% in yearly energy production. This is due to the fact that a receiver with a lower absorptive capacity will take in a lower quantity of sunlight and will transfer a lower quantity of heat to the heat-transfer fluid, hence lowering the overall efficiency of the system [30]. The objective of this research was to examine the effect of increasing the receiver's capacity to absorb solar radiation on the total energy output of a parabolic trough system. To achieve this objective, a parabolic trough system was designed, and receiver absorbance values were varied. The study showed that the receiver absorbance values can affect the energy output of the parabolic trough system.

2. GEOGRAPHICAL AND METEOROLOGICAL DATA

Amman, Jordan's capital city, is situated in the country's northwest, surrounded by hills and valleys. It has a land area of 1,680 square kilometers and a population of around 4 million people. Amman is located at an elevation of 1,000 meters above sea level, giving it a warm and pleasant environment all year. Because to its position on the eastern rim of the Mediterranean, the city enjoys a semi-arid climate with hot, dry summers and moderate, wet winters.

According to meteorological statistics, the average temperature in Amman varies from 23 °C to 32 °C in the summer and 7 °C to 14 °C in the winter. July and August are the warmest months, with average temperatures about 32 °C, while December and January are the coldest, with average temperatures around 7 °C. Amman receives around 250 mm of rain each year, with the most of it falling between November and March.

Amman is situated in a sun-rich zone, making it a great site for solar energy generation. The city enjoys an average of 300 days of sunshine each year, with at least 7 hours of sunlight per day, which is a substantial benefit for solar power production. According to meteorological statistics, the average sun radiation levels in Amman vary from 5 to 7 kilowatt-hours per square meter per day, depending on the time of year. This allows the city to produce considerable amounts of solar electricity throughout the year. Figure 1 shows the sunshine hours' distribution at Amman Jordan over the year.

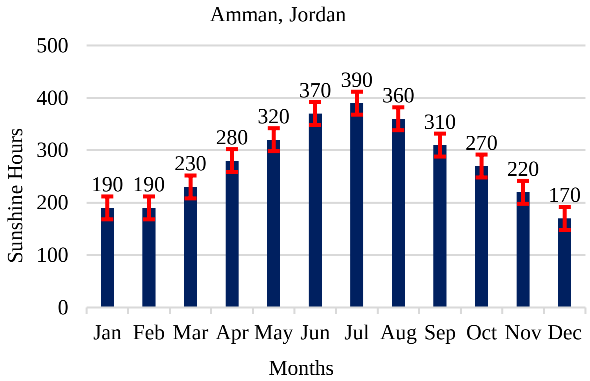

Figure 1. Sunshine hours in Amman, Jordan, throughout the year

3. SOLAR CALCULATION

The energy emitted by the sun that reaches the Earth's surface is known as solar radiation. It is essential to the design and operation of solar applications, such as solar energy systems and solar water heaters. Depending on factors such as latitude, altitude, and weather, the amount of solar radiation that reaches a certain region might vary. Using mathematical models that account for location, time of year, atmospheric and surface conditions, and other factors is the most prevalent approach of estimating solar radiation. These models predict the quantity of sunlight that will strike a certain region by analyzing information from weather stations, satellites, and other sources.

Solar declination, the sunset hour angle, extraterrestrial radiation, and monthly average solar radiation on a horizontal surface were calculated to create a mathematical model.

$$\delta = 23.45\sin(2\pi(284+n)/365) \quad (1)$$

$$\cos\omega s = \tan\phi\tan\delta \quad (2)$$

$$H_o = \frac{24\times 3600 G_{SG}}{\pi}\times(1+0.033\cos(\frac{360n}{365})\times \times(\cos\phi\cos\delta\sin\omega_s + (\pi\omega_s/180)\sin\phi\sin\delta) \quad (3)$$

4. RESULTS AND DISCUSION

Due to its great effectiveness in concentrating solar radiation, parabolic trough systems are frequently utilized for solar thermal applications. Nevertheless, a number of variables, such as the position and height of the receiver, can impact how well these systems' function. The receiver's height, in particular, has a significant impact on how much solar energy the device can collect.

The amount of solar radiation that a parabolic trough system collects determines how much energy the system will produce. The receiver in the system, which is in charge of taking solar energy and transforming it into thermal energy, is essential to this process. More solar radiation may be gathered by the Parabolic Trough System by raising the receiver absorbance's height, which increases the quantity of energy produced each hour. This is so that a greater proportion of the solar radiation entering the receiver may be intercepted, resulting in higher levels of absorption and a more effective energy conversion. Also, raising the receiver absorbance's height can aid in lowering shadowing and other environmental loss rates, which can further boost the system's overall energy production. The amount of energy generated per hour can ultimately be significantly increased by raising the height of the receiver absorbance in the Parabolic Trough System, making this technology an even more appealing choice for satisfying our energy needs in a sustainable and environmentally friendly manner.

On the 10th of December, which is the day with the least amount of energy from the sun, raising the height of the receiver can have a big effect on how much energy is collected each day. As the sun's rays travel farther through the earth's atmosphere, they are more likely to be scattered, absorbed, and reflected. This reduces the amount of solar radiation that reaches the surface of the earth. By raising the height of the receiver, atmospheric noise is cut down. This lets more of the sun's rays be caught and turned into energy. This can have a big effect on how much energy is made in places where the sun's rays hit the ground at a low angle, like at high latitudes or in the winter. Also, increasing the height of the receiver increases the surface area that can be used to collect solar radiation. This can lead to a further increase in the amount of energy made each day. But it's important to note that the best height for the receiver will depend on a number of things, such as the location's latitude, terrain, and weather. Because of this, it's important to carefully think about these things when designing and installing solar energy systems. Figure 2 shows the energy production per hour of the 10th of December as it is clear that the energy amount produced by the parabolic trough systems duplicated each time that the receiver height is duplicated. The produced energy amount was at the maximum as 1.5, 3, 5, and 6 kWh for the 25, 50, 75, and 100%, respectively.

By increasing the height of the receiver, the system will be able to produce more energy every month of the year as well as every month individually. This is due to the fact that a greater receiver height makes it possible for the system to absorb more sunlight, which in turn increases the effectiveness of the absorption rate.

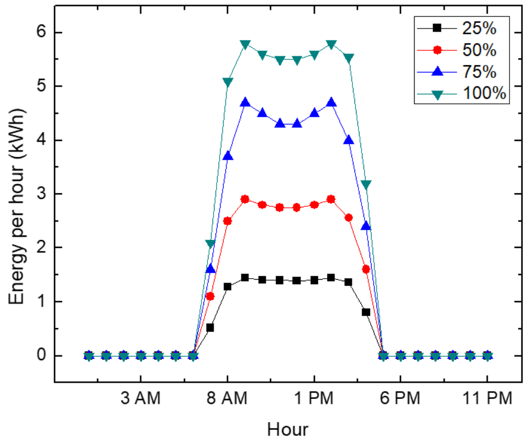

Figure 2. Energy amount produced at 10th December for the four parabolic trough systems with different receiver height

The parabolic trough system is able to track the movement of the sun as it travels across the sky. This ensures that the receiver is always in the ideal position to take in the most quantity of sunlight. As a consequence, there is an increase in the concentration of solar energy at the receiver, which is then turned into thermal energy that can be used to create electricity. This enhanced efficiency of the absorption rate can have a major impact on the system's ability to produce energy, enabling it to produce more energy with the same amount of sunlight that was previously available. In general, elevating the height of the receiver in a parabolic trough system has the potential to result in more efficient energy production. This is vital for satisfying the ever-increasing demand for energy throughout the world while simultaneously cutting carbon emissions. Figure. 3shows the energy production of the parabolic trough system over the year in kWh where the maximum production was in July of all receiver height percentage with a value of 60, 90, 140, and 160 kWh for 25%, 50%, 75% and 100%, respectively. The minimum energy production was during December for all receiver height percentage as it's the worst month in the solar radiation production.

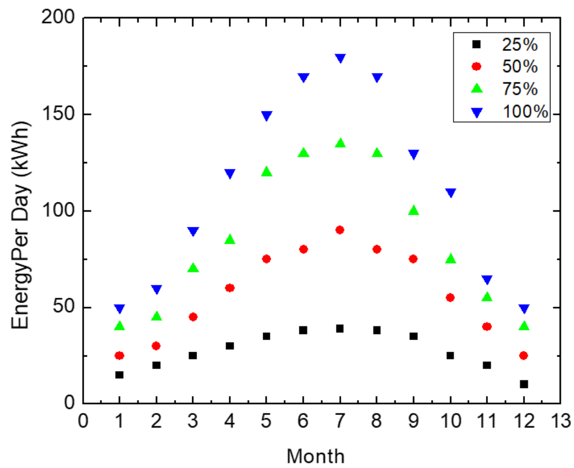

Figure 3. Energy production over the year in kWh

This work focuses on a specific research topic related to the impact of variable receiver absorption on energy production in parabolic trough systems. The title highlights the use of comprehensive analysis and evaluation techniques to investigate this particular aspect of parabolic trough systems, which are widely used in solar thermal energy production. In comparison to other works in the field, this title stands out due to its emphasis on the comprehensive nature of the analysis and evaluation. It suggests that the research will provide a thorough and in-depth examination of the impact of variable receiver absorption, which may differentiate it from other studies that may have only examined specific aspects or variables of parabolic trouble systems.

Additionally, the use of the term "variable receiver absorbance" in the title indicates that the research may be investigating how changing the absorbance properties of the receiver in parabolic trowel systems can affect energy production. This specific focus on variable absorption sets it apart from other works that may have examined fixed or constant absorption in parabolic trough systems. Overall, the title suggests that the research is conducting a comprehensive analysis of the impact of variable receiver absorption on energy production in parabolic trough systems, which may differentiate it from other works in the field and contribute to a deeper understanding of this aspect of solar thermal. energy production.

5. CONCLUSION

In conclusion, the findings of this research project offer undeniable proof that the height of the receiver in a parabolic trough system has a substantial bearing on the amount of energy that is generated by the system. According to the findings of the investigation, the amount of energy produced is exactly proportional to the height of the receiver up to a specific threshold. In particular, it was discovered that raising the height of the receiver up to a maximum of one hundred percent of the parabolic trough resulted to a corresponding increase in the amount of energy that was collected. Nevertheless, after this height, the association between receiver height and energy output became less evident, indicating the presence of additional factors that may come into play at greater heights. This height was chosen since it was the maximum height at which the relationship was observed.

The findings have significant repercussions for the design and optimization of parabolic trough systems, which are extremely common in the generation of solar thermal energy. According to the findings, increasing the height of the receiver can be a straightforward and efficient strategy to increase the amount of energy that is produced, at least up to a certain degree. After this point, it is possible that other elements may need to be taken into consideration in order to further improve the performance of the system. his study emphasizes the importance of receiver height in parabolic trough system design and gives a framework for further research. Understanding solar thermal energy production parameters can assist optimize these technologies and facilitate the transition to a more sustainable and energy-efficient future.

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