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Research article

The effect of solar tower height on its energy output at Ma'an-Jordan

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Abstract: The solar power tower is a concentrated solar energy application that uses a receiver to capture reflected sunlight from the mirror field. Solar energy is seen as one of the solutions to the problem of climate change as it is environmentally friendly. In this work, the production of energy from a solar tower in the Ma'an region of southern Jordan was studied using a simulation program of 3D-Energy. The dependency of the power output on the tower height is presented while showing that greater power production can be facilitated by optimizing the height of the tower.

Keywords: solar power tower; concentrated solar thermal; power output; pollution-free energy

1. Introduction

Jordan's traditional sources of energy are the largest problem and the main cause of disability in many vital sectors of Jordan. On the other hand, the bright side, Jordan is considered a renewable energy country, since Jordan has about 300 sunny days a year and a high solar radiation rate compared to neighboring countries and the rest of the world. Here is the importance of investment in this sector as it is a national need [1–5]. Renewable energy is the best solution and alternative to traditional energy generated by conventional fuels because renewable energy is environmentally friendly as it does not contribute to polluting the environment and does not produce harmful emissions. Therefore, the solution of using renewable energy is not to replace the traditional energy sources, but to solve the problem of environment and climate change that occupies the world [6–26].

The world's increasing factors of increasing modernity and the unacceptably high rate of population growth in some countries have led to increased demand for energy. Thus, there is an urgent need to use energy sources more effectively than before, and research and development of alternative energy sources [11,13,16–20,22,24,26–33]. Exploiting the energy available from renewable energy effectively and with high momentum has become an urgent need for many governments around the world to give utmost importance to providing alternatives to traditional energy. Solar energy is the most suitable and most efficient option in many countries of the world. Therefore, focusing on solar energy systems to generate energy, especially electricity, directly or indirectly is an urgent and necessary national necessity [34–39].

Mullett (1987) presented a study on the calculation of energy efficiency generated by the solar tower and found that investment in solar towers is only feasible on a large scale [40]. Hence, the task of researchers in the development of the system of solar towers to be more effective and meet the need for energy. Another study was handled by Padki & Sherif (1988) on the tower, investigating the effects of different configurations on tower performance and efficiency [41].

Reinforced concrete and conventional iron bars are the methods used to build solar power towers available these days, bearing in mind that conventional iron bars are more economically efficient when compared to reinforced concrete [42]. Note that the foundations of installation of solar towers are made of reinforced concrete.

To generate power from solar towers effectively, high towers are more appropriate to reduce losses from the field of mirrors. However, the height of the solar towers surrounded by several obstacles, including wind speed, the weight of the receiver of solar radiation and seismic loads, which are the main factors affecting the design of solar towers [43].

Simulations programmes are the appropriate tool for studying and analyzing data from different regions around the world for their ability to collect and utilize these data using various software programs. They also have the ability to present results in a way that makes decision making very easy [44].

2. Geographical and meteorological data

The southern Jordan is one of the regions with a high rate of solar radiation, knowing that Jordan is considered one of the highest countries in the world with the rate of solar radiation compared to the neighboring countries and the various countries of the world. Ma'an, located in southern Jordan and 200 km from Amman, the capital of Jordan. Figure 1 represents the number of sunshine days and hours of Ma'an for each month [45].

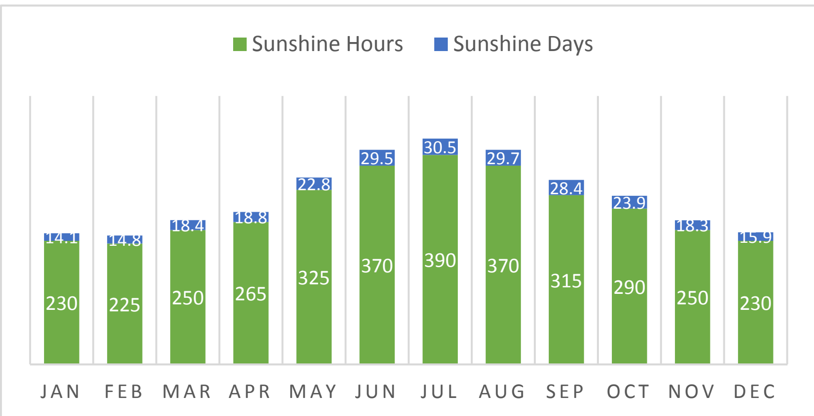

Figure 1. Number of sunshine days and hours per month Ma'an-Jordan [45].

Daily temperatures are of great importance in the study of locations in terms of their relevance to the application of renewable energy systems where temperatures are one of the most important factors for the type of application used. Figure 2 shows the daily and annual temperature distribution in Ma'an-Jordan of the air and the ground at different heights [20,45]. The 10th of December is the worst day in solar radiation in Jordan and the design of renewable energy systems depends on this day to achieve successful designs knowing that the best month in terms of the value of solar radiation is August and worse are December and January.

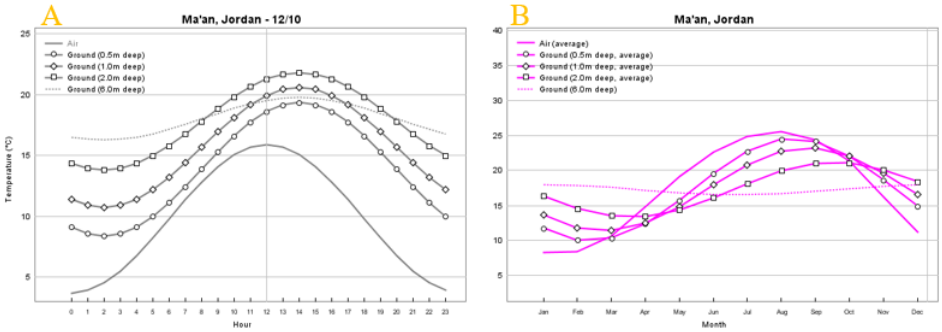

Figure 2. Temperature distribution based on daily (A) and annual (B) measurements in Ma'an-Jordan.

3. Simulation results and discussion

Figure 3 shows a schematic of the Energy 3D simulation of two fields of solar tower. The first field consist of eight heliostats and a solar tower with a height of 16 m while the second has the same number of the heliostats but a solar tower with a height of 32 m.

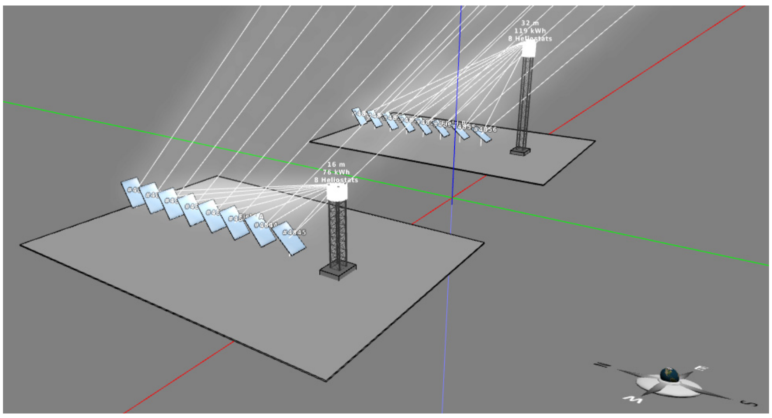

Figure 3. Schematic of the Energy 3D simulation of two solar tower fields.

Figure 4 shows the solar intensity over the two solar tower fields at 10^{th} of each month during the year. The maximum intensity of the two fields was in July 10^{th} while the lowest was in January and December 10^{th}. From the intensity map it is noted that in the solar field with height tower the concentration of the sun rays was better make the solar power production higher in the second field comparing to the first field.

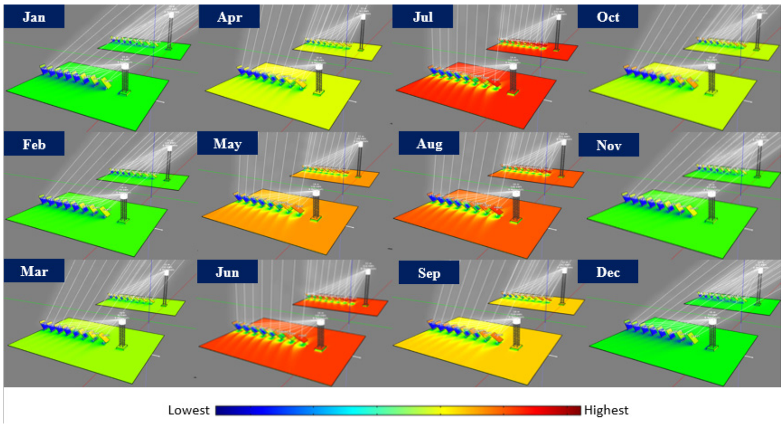

Figure 4. Solar intensity over the two solar tower fields.

Figure 5 present the energy output from the first solar tower field with a height of 16 m and based on eight heliostats named 4837, 4838, 4839, 4840, 4841, 4842, 4844 and 4845 during a selected date which is the 10th of December as the worst sunny day during the year (A) and the energy output during each month of the year (B). The peak hours of the selected date started from 07:00 tile 18:00 with a maximum of 2.7 kWh at 12:30 based on heliostat 4845 and a minimum of 0.75 kWh for the heliostats 4837–4841. The maximum production during the year was in July with a value of 35 kWh based on heliostat 4845 the closest heliostat to the tower and a minimum value of 7.5 kWh based on the fairest heliostats from the tower. Figure 6 shows the production energy from the second solar tower field 32 m with eight heliostats named 4849, 4850, 4851, 4852, 4853, 4854, 4855 and 4856. The maximum daily production for the worst day in the year i.e. 10th of December is 2.6 kWh for the closest heliostat 4856 to the tower while the lowest production was for the heliostats far away from the tower 4849, 4850, 4851, 4852 and 4853. The peak energy production during the year was in July with a value of 37.5 kWh for the closest heliostat to the tower and the minimum was for the heliostat far away from the tower. For both fields the minimum production was during January and December and the maximum was during July and August.

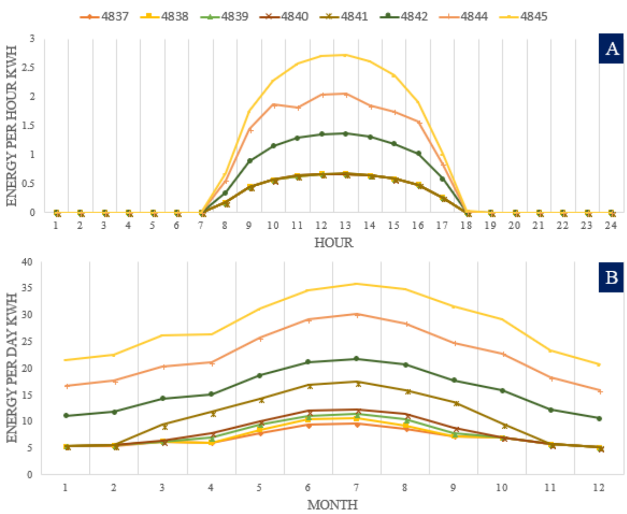

Figure 5. Energy output from the first solar tower field 16 m for a day (A) and for a year (B).

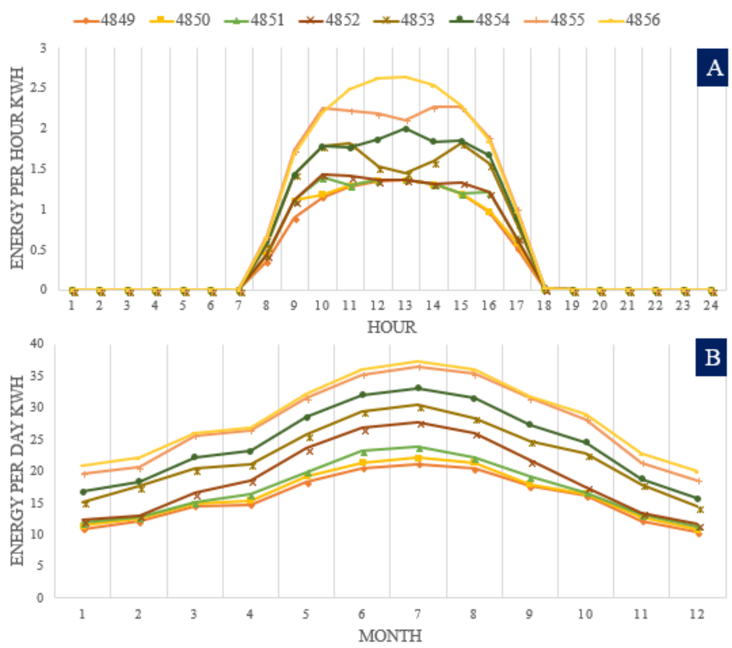

Figure 6. Energy output from the first solar tower field 32 m for a day (A) and for a year (B).

4. Conclusion

The relationship between the height of the solar tower and its ability to produce energy was studied. To complete this study, two solar towers were used, 16 and 32 meters high. It was concluded that:

- The greater the height of the solar tower, the greater the energy production. The energy production is proportional to the tower height.
- The maximum amount of the energy production over the selected date which is the 10th of December i.e. the worst solar radiation day, is in between 07:00 to 18:00 day time.
- The maximum amount of the energy production over the year is in June while the lowest energy production was in December and January.
- The closest mirrors to the tower are the most capable of producing energy because it works to focus the solar radiation very effectively compared to the mirrors farther from the tower.
- The total annual power production from the first solar tower field of 16 m height is 1.3 MWh while the total annual power production from the second field with a tower height of 32 m is 2 MWh.

Conflict of interest

The author declares there are no conflicts of interest in the paper.

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