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P4_1 Maximum Power Generation From Solar Panels

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Abstract

Solar panels are a source of renewable energy that become less efficient as they heat up. The intensity of light from the Sun and temperature increases as the distance from it decreases. In this paper, we investigated how to maximise the power generated from a solar panel by moving it closer to the Sun. We determined the ideal distance from the Sun to be 0.258 AU, with a peak power generation of 1450 W.

Introduction

Solar panels are an environmentally friendly source of renewable energy which is seeing widespread use throughout the UK. In this paper, we consider the effects on the power generated and the efficiency of a solar panel when it is moved closer to the Sun. Our aim is to find the distance where the power generated by the solar panel is at a maximum.

Theory

The power P incident on an object with projected area A at a distance a from a radiating source of luminosity L is given by:

$$P = \frac{LA}{4\pi a^2}, \tag{1}$$

where P is the product of the incident flux from the Sun multiplied by the object's projected area [1]. In this paper, we will be using estimates based on real solar panels as a basis for our calculations. Typically, the efficiency e of a high performing modern day solar panel is around 20% [2], so $e = 0.2$. The temperature coefficient (or change in efficiency) δe for our solar panel is -0.258% per degree around 25°C [3], so $\delta e = 0.00258$. We will assume this follows a linear relationship for a large range of temperatures, though this may not necessarily be true as the solar panel may be damaged under extreme conditions. We derived the efficiency as:

$$e = 0.2(1 - \delta e|T - T_e|), \tag{2}$$

where T_e is the temperature required for peak efficiency, which is 298 K (25°C). At $T = 298$ K, the solar panel will be operating at peak efficiency, so the modulus term goes to 0 therefore $e = 0.2$.

The temperature T of an object at a distance a from the Sun (with surface temperature $T_\odot$ and radius $R_\odot$) can be expressed as:

$$T = T_\odot\sqrt{\frac{R_\odot}{2a}}, \tag{3}$$

where we will be assuming an albedo [4] (the reflection of light) of 0, as this will simplify the model. We can now substitute T into Equation (2):

$$e = 0.2\left(1 - \delta e\left|T_\odot\sqrt{\frac{R_\odot}{2a}} - T_e\right|\right). \tag{4}$$

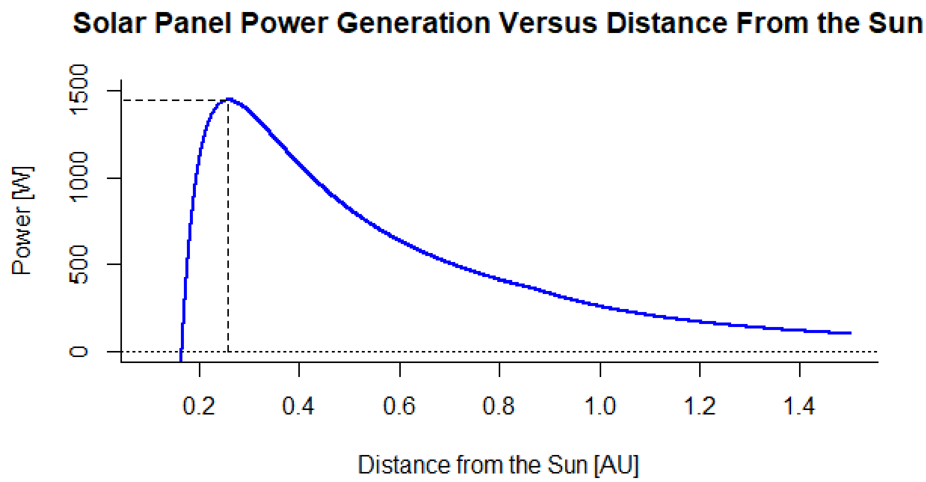

Figure 1: A graph we produced demonstrating the power generated by the solar panel against distance from the Sun, assuming negligible albedo and a projected area of 1 m^2.

Therefore, the power generated by the solar panel is the product of Equation (1) and Equation (4):

$$P = \frac{0.2LA}{4\pi a^2}\left(1 - \delta e\left|T_\odot\sqrt{\frac{R_\odot}{2a}} - T_e\right|\right). \quad (5)$$

We will assume the solar panel will function as intended while under extreme temperatures.

Results

For this paper, we chose to use a solar panel with a value of A of 1 m^2. Figure (1) demonstrates a graphical solution to Equation (5), where the peak was found using the derivative of P with respect to a. Through numerical methods, the maximum power generated was found to be 1450 W at a distance of 0.258 AU.

Conclusion

In summary, we have found the ideal distance from the Sun to place a solar panel for the maximum amount of power generation to be obtained. We have determined the distance to be 0.258 AU where the power generated was 1450 W.

We have assumed a linear relationship between the change in efficiency and temperature, though this may not be true for the temperature range that is required in this paper. Further study may aim to understand the relationship between efficiency and temperature for a wide range of temperatures, possibly for spacecraft missions.

The temperature at a distance of 0.258 AU from the Sun is approximately 548 K by substituting in this distance value into Equation (3). This could cause significant damage to the solar panel as it was not intended for these devices to be used at this temperature.

References

[1] `http://www.astronomy.ohio-state.edu/~thompson/161/lecture_24_web.pdf` [Accessed 14 October 2019]

[2] `https://energyinformative.org/solar-panel-efficiency` [Accessed 2 October 2019]

[3] `https://www.civicsolar.com/article/how-does-heat-affect-solar-panel-efficiencies` [Accessed 2 October 2019]

[4] `https://www.astro.princeton.edu/~strauss/FRS113/writeup3/` [Accessed 14 October 2019]