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Solar Panel Colling System Design Using Solid Hydrate Salt

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Abstrak: Energi surya merupakan energi alternatif yang melimpah, terbarukan, dan tidak menghasilkan emisi gas rumah kaca, sehingga berpotensi untuk dikembangkan menjadi energi pengganti energi fosil sebagai sumber pembangkit listrik. Teknologi utama dalam pemanfaatan energi surya adalah panel surya, panel surya terdiri dari sel surya yang terbuat dari bahan semikonduktor, seperti silikon. Sel surya ini mengubah energi foton dari sinar matahari menjadi energi listrik melalui efek fotovoltaik. Perubahan suhu sel surya dipengaruhi oleh suhu lingkungan, awan, dan kecepatan angin tempat panel surya diletakkan. Suhu udara yang sangat tinggi dapat mempengaruhi kinerja panel surya dimana suhu optimal panel surya adalah 25°C, setiap kenaikan suhu lingkungan dapat menurunkan daya keluaran dan juga tegangan keluaran pada panel surya. Penelitian ini berfokus pada analisis sistem pendingin panel surya yang menggabungkan penggunaan hidrat garam padat dan heatsink. Hidrat garam padat memiliki kemampuan untuk menyerap panas saat mencair, sehingga menjadi bahan pendingin yang efektif. Sementara itu, heatsink berperan dalam meningkatkan perpindahan panas dari panel surya ke lingkungan sekitar. Kombinasi hidrat garam padat dan heatsink diharapkan dapat memberikan solusi pendinginan panel surya yang tidak hanya efektif dan efisien, tetapi juga ramah lingkungan. Dengan menggunakan kedua komponen ini, penelitian ini diharapkan dapat memberikan kontribusi terhadap pengembangan teknologi panel surya yang lebih efisien dan berkelanjutan. Selain itu, hasil penelitian ini juga bertujuan untuk memberikan rekomendasi desain sistem pendingin panel surya yang optimal untuk berbagai kondisi lingkungan, sehingga dapat meningkatkan kinerja dan umur panel surya.
Kata kunci: energi surya, panel surya dan suhu lingkungan

Abstract: *Solar energy is an alternative energy that is abundant, renewable, and does not produce greenhouse gas emissions, so it has the potential to be developed into energy to replace fossil energy as a source of electricity generation. The main technology in the utilization of solar energy is solar panels, solar panels consist of solar cells made of semiconductor materials, such as silicon. These solar cells convert photon energy from sunlight into electrical energy through the photovoltaic effect. Changes in the temperature of solar cells are affected by the ambient temperature, clouds, and wind speed where the solar panel is placed. Very high air temperatures can affect the performance of solar panels where the optimal temperature of solar panels is 25°C, any increase in ambient temperature can reduce the output power and also the output voltage on solar panels. This research focuses on analyzing a solar panel cooling system that combines the use of solid salt hydrate and heatsinks. Solid salt hydrate has the ability to absorb heat as it melts, making it an effective cooling material. Meanwhile, the heatsink plays a role in enhancing heat transfer from the solar panel to the surrounding environment. The combination of solid salt hydrate and heatsink is expected to provide a solar panel cooling solution that is not only effective and efficient, but also environmentally friendly. By using these two components, this research is expected to contribute to the development of more efficient and sustainable solar panel technology. In addition, the results of this research also aim to provide optimal solar panel cooling system design recommendations for various environmental conditions, so as to improve the performance and longevity of solar panels002E*
Keywords: *solar energy, solar panel and environmental temperature*

1. INTRODUCTION

Energy is an essential need for the survival of humanity and modern civilization [1] [2]. Our dependence on energy is increasing along with the development of technology and global population [3]. Conventional energy sources, such as fossil fuels, are not only limited in quantity but also contribute significantly to climate change and environmental damage [4] [5]. Therefore, the search for alternative energy sources that are sustainable and environmentally friendly is crucial [6] [7]. One of the most promising alternative energy sources is sunlight [8]. Sunlight is an abundant, renewable energy source that does not produce greenhouse gas emissions [9]. The enormous potential of solar energy can be utilized to meet the increasing global energy demand [10]. The utilization of solar energy can also help reduce dependence on fossil fuels, reduce air pollution, and mitigate climate change.

The main technology in solar energy utilization is solar panels. Solar panels consist of solar cells made of semiconductor materials, such as silicon [11] [12]. These solar cells convert photon energy from sunlight into electrical energy through the photovoltaic effect [13]. Changes in the temperature of solar cells are affected by the ambient temperature, clouds, and wind speed where the solar panel is placed [14]. Very high air temperatures can affect the performance of solar panels where the optimal

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temperature for solar panels is 25°C [15]. Any increase in ambient temperature can reduce the output power and also the output voltage on the solar panel.

This research focuses on analyzing solar panel cooling systems using solid salt hydrate and heatsinks. Solid salt hydrate has the property of absorbing heat when melted, so it can be used as a cooling material. The heatsink serves to increase heat transfer from the solar panel to the surrounding environment. The combination of solid salt hydrate and heatsink is expected to provide an effective, efficient, and environmentally friendly solar panel cooling solution. This research is expected to contribute to the development of more efficient and sustainable solar panel technology. The results of this research are also expected to provide recommendations for the optimal solar panel cooling system design for various environmental conditions.

2. MATERIALS AND METHODS

The author conducts the research stages based on a flow chart that has been compiled to facilitate the analysis and implement a solar panel cooling system design using solid salt hydrate as shown in Figure 1 below.

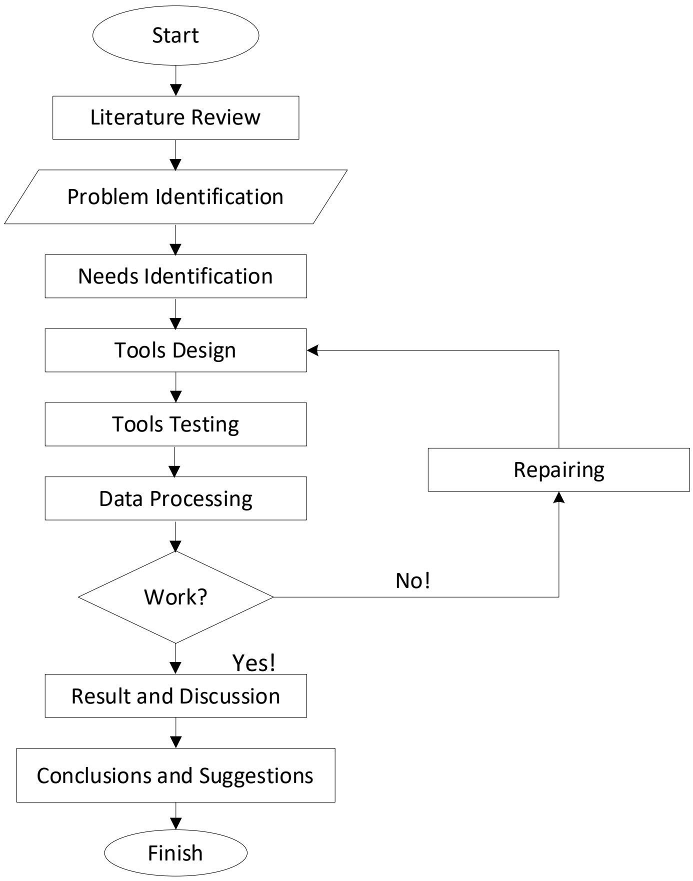

Figure 1. Research Flow Chart

Basically, this research started by identifying the main problem, namely the utilization of solid salt hydrate as a coolant in solar panels and its effect on the performance of these panels [16]. The initial steps included a literature study to gather relevant information and theoretical foundations from various sources. Next, the researcher identified all the tools and materials required for the study such as solar panels, solid salt hydrate, temperature sensors, and light intensity measuring devices. Preparation of the solid salt hydrate was done to ensure its condition was ready for use in the experiments.

Data was collected by measuring solar panel temperature, air temperature, light intensity, output voltage, and output power at specific time intervals [17]. Data was collected for solar panels with and without solid salt hydrate cooling for performance comparison. Once the data was collected, the researcher conducted an evaluation and analysis to identify errors and repeat the measurements if

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necessary. In-depth analysis was conducted using statistical methods to find patterns and relationships in the data, as well as the effect of cooling on solar panel efficiency. The research concludes by formulating conclusions that answer the research questions and provide a better understanding of the use of solid salt hydrate as a coolant in solar panels.

Specifically, the research method used in this article is an experimental method with a quantitative approach. This research aims to analyze the effect of using solid salt hydrate as a coolant on the performance of solar panels. This research was conducted by comparing the performance of solar panels with and without solid salt hydrate coolant. The variables measured in this study are solar panel temperature, light intensity, output voltage, and output power. This research was conducted using two identical solar panels, one solar panel was equipped with a solid hydrate salt cooler, while the other solar panel was not equipped with a cooler. Both solar panels were then placed in the same location and faced towards the sun. Measurements were taken at the same time to ensure similar environmental conditions.

3. RESULTS AND DISCUSSION

3.1 Measurement Data on Solar Panels on The First Day

The measurement process is carried out on the outside and inside of the solar panel, Temperature data collection on solar panels is carried out at nine points spread across the surface of the panel. using a temperature sensor placed at a distance of 10 cm from the surface of the solar panel. Measurements were carried out in the time range between 09:00 WIB and 17:00 WIB, with a measurement interval of once every 1 hour to obtain representative data periodically.

Table 1. First Dat Measurement Data Table

First Day		Temperature		Isc		Voc	
Time (West Indonesia Time)	**Light Intensity**	**With Solid Hydrate Salt Cooler and Heatsink**	**Uncooled**	**With Solid Hydrate Salt Cooler and Heatsink**	**Uncooled**	**With Solid Hydrate Salt Cooler and Heatsink**	**Uncooled**
9:00	515,5 W/m²	41.5	43.4	1.5	1.4	21,20	19,80
10:00	900,6 W/m²	42.6	45	4.1	3.3	21,20	20,50
11:00	1300 W/m²	50.4	50	4.1	3.4	20,50	18,50
12:00	521,8 W/m²	41.8	42.6	3.2	2.1	21,30	19,20
13:00	392,3 W/m²	38	38.9	2.4	1.6	21,50	20,15
14:00	657,4 W/m²	39.7	44.9	3.2	2.5	22,50	21,50
15:00	882,5 W/m²	50.6	51.5	4.2	3.1	22,70	21,50
16:00	596,6 W/m²	41.6	42.6	2.1	1.1	21,50	19,40
17:00	785,7 W/m²	37	37.9	2.6	1.9	20,60	19,40

3.1.1 Temperature Data

As a sample, pay attention to the temperature data at 09.00 and 10.00 am on the first day below:

Table 2. Temperature Data at 09.00 am

	Uncooled						With Cooled					
No	Outside Panel Temperature			In-Panel Temperature			Outside Panel Temperature			In-Panel Temperature		
	Left Section	Center Section	Right Section	Left Section	Center Section	Right Section	Left Section	Center Section	Right Section	Left Section	Center Section	Right Section
1	45,1	45,8	42,5	42,8	42,3	40,8	45,7	49,8	46,2	35,8	34,6	34,5
2	44,9	44,1	43,1	43,2	42,8	41,7	47,6	50,5	46,4	34,6	35,1	34,3
3	43,8	43,7	42,2	42,6	41,9	41,1	46,6	49,3	46,1	36,6	36,3	36,5
Avg.	44,6	44,5	44,6	42,9	42,3	41,2	46,6	49,8	46,2	35,6	35,7	35,1
Total	44,6			42,1			47,5			35,4		
Temperature	43,4						41,4					

As can be seen from the data above, there is a significant difference between the average temperature inside solar panels using solid salt hydrate coolers and heatsinks and the temperature inside solar panels without coolers. The temperature inside the solar panels without coolant tends to be higher, reaching 42.1°C, compared to the temperature inside the solar panels using coolant which only reaches 35.4°C.

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The temperature difference between the uncooled solar panel and the cooled solar panel is about 6.7°C, with the light intensity reaching 515.5 W/m².

Table 3. Temperature Data at 10.00 am

	Uncooled						With Cooled					
	Outside Panel Temperature			In-Panel Temperature			Outside Panel Temperature			In-Panel Temperature		
No	Left Section	Center Section	Right Section	Left Section	Center Section	Right Section	Left Section	Center Section	Right Section	Left Section	Center Section	Right Section
1	43,3	43,3	41,9	49,1	49,9	49,4	46,4	48,1	47,4	38,5	37,1	35,9
2	40,8	42,6	41,7	47,2	49,3	49,3	48,1	49,8	49,2	37,1	37,2	36,4
3	38,7	42,1	41,6	43,3	47,6	49,1	46,1	49,0	48,8	39,1	37,3	37,1
Avg.	40,9	42,6	41,7	46,5	48,9	49,2	46,8	48,9	48,3	38,2	37,2	36,4
Total	41,7			48,2			48,0			37,2		
Temperature	44,9						42,6					

Then from the second data at 10:00, there is a significant difference between the average temperature inside the solar panel using solid salt hydrate coolant and heatsink and the temperature inside the solar panel without coolant. The temperature inside the solar panels without cooling tends to be higher, reaching 48.2°C, compared to the temperature inside the solar panels using cooling which only reaches 37.2°C. The temperature difference between the uncooled solar panel and the cooled solar panel is about 11°C, with the light intensity reaching 900.6 W/m².

3.1.2 Effect of Temperature on Current

Table 4. Effect of Temperature on Current

Temperature			**Isc**	
Time (West Indonesia Time)	**With Solid Hydrate Salt Cooler and Heatsink**	**Uncooled**	**With Solid Hydrate Salt Cooler and Heatsink**	**Uncooled**
9:00	41.5	43.4	1.5	1.4
10:00	42.6	45.0	4.1	3.3
11:00	50.4	50.0	4.1	3.4
12:00	41.8	42.6	3.2	2.1
13:00	38.0	38.9	2.4	1.6
14:00	39.7	44.9	3.2	2.5
15:00	50.6	51.5	4.2	3.1
16:00	41.6	42.6	2.1	1.1
17:00	37.0	37.9	2.6	1.9

To analyze hourly temperature and current data, we can calculate the current efficiency from 09.00 to 17.00, in conditions with cooling and without cooling. For example, here is the analysis at 09.00 using the formula:

$$\eta = \frac{(1{,}5-1{,}4)}{1{,}4} \times 100\%$$
$$\eta = \frac{0{,}1}{1{,}4} \times 100\%$$
$$\eta = 0{,}07 \times 100\%$$
$$\eta = 7\%$$

3.1.3 Effect of Temperature on Voltage

Table 5. Effect of Temperature on Voltage

Temperature			**Voc**	
Time (West Indonesia Time)	**With Solid Hydrate Salt Cooler and Heatsink**	**Uncooled**	**With Solid Hydrate Salt Cooler and Heatsink**	**Uncooled**

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9:00	41.5	43.4	21,20	19,80
10:00	42.6	45.0	21,20	20,50
11:00	50.4	50.0	20,50	18,50
12:00	41.8	42.6	21,30	19,20
13:00	38.0	38.9	21,50	20,15
14:00	39.7	44.9	22,50	21,50
15:00	50.6	51.5	22,70	21,50
16:00	41.6	42.6	21,50	19,40
17:00	37.0	37.9	20,60	19,40

To analyze the hourly temperature and voltage data, we can calculate the voltage efficiency from 09:00 to 17:00, in the condition with cooling and without cooling. For example, here is the analysis at 09:00 using the formula:

$$\eta = \frac{(21{,}20 - 19{,}80)}{19{,}80} \times 100\%$$

$$\eta = \frac{1{,}4}{19{,}80} \times 100\%$$

$$\eta = 0{,}07 \times 100\%$$

$$\eta = 7\%$$

3.1.4 Effect of Temperature on Solar Panel Power

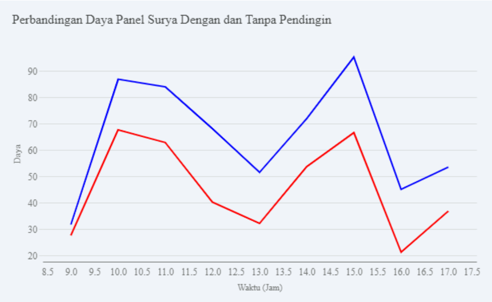

Figure 2. First Day Temperature to Power Efficiency Graph

Overall, this hourly analysis shows that solid salt hydrate coolers and heatsinks consistently improve solar panel performance throughout the day. The resulting power increase varied depending on temperature and other environmental conditions, but overall, the use of coolants proved to be very effective in increasing the efficiency of the solar panels and generating more electrical energy.

3.2 Measurement Data on Solar Panels on the Second Day

The measurement process is carried out on the outside and inside of the solar panel, Temperature data collection on solar panels is carried out at nine points spread across the surface of the panel. using a temperature sensor placed at a distance of 10 cm from the surface of the solar panel. Measurements were carried out in the time range between 09:00 WIB and 17:00 WIB, with a measurement interval of once every 1 hour to obtain representative data periodically.

Table 6. Second Day Measurement Data Table

Second Day		Temperature		Isc		Voc	
Time (West Indonesia Time)	Light Intensity	With Solid Hydrate Salt Cooler and Heatsink	Uncooled	With Solid Hydrate Salt Cooler and Heatsink	Uncooled	With Solid Hydrate Salt Cooler and Heatsink	Uncooled
9:00	247,4 W/m²	3.1	2.3	3.1	2.3	21,60	20,50
10:00	408,2 W/m²	3.8	3.1	3.8	3.1	21,80	20,60
11:00	686,6 W/m²	4.2	2.2	4.2	2.2	21,70	19,50
12:00	980,0 W/m²	4.5	3.4	4.5	3.4	21,60	20,10
13:00	127,6 W/m²	4.4	3.7	4.4	3.7	21,40	20,50
14:00	1053,7 W/m²	4.5	3.8	4.5	3.8	21,40	19,80
15:00	928,6 W/m²	4.5	3.9	4.5	3.9	21,90	20,10
16:00	697,7 W/m²	2.2	1.1	2.2	1.1	20,90	19,80
17:00	733,8 W/m²	2.7	1.7	2.7	1.7	21,50	19,30

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3.2.1 Temperature Data

As a sample, pay attention to the temperature data at 09.00 and 17.00 on the first day below:

Table 7. Temperature Data at 09.00 am

	Uncooled						With Cooled					
No	Outside Panel Temperature			In-Panel Temperature			Outside Panel Temperature			In-Panel Temperature		
	Left Section	Center Section	Right Section	Left Section	Center Section	Right Section	Left Section	Center Section	Right Section	Left Section	Center Section	Right Section
1	32,8	32,9	32,7	34,4	34,7	34,8	31,9	33,2	32,1	31,2	32,5	31,3
2	32,6	32,5	32,5	34,7	34,2	34,6	32,1	33,5	32,2	30,1	30,2	29,8
3	32,2	32,6	32,6	33,9	34,1	34,5	31,4	32,1	31,3	30,9	30,1	30,4
Avg.	32,5	32,7	32,5	34,3	34,3	34,6	31,8	32,9	31,9	30,7	30,9	30,5
Total	32,6			34,4			32,2			30,7		
Temperature	33,5						31,5					

As can be seen from the table above, there is a significant difference between the average temperature inside the solar panels using solid salt hydrate coolers and heatsinks and the temperature inside the solar panels without coolers. The temperature inside the solar panels without cooling tends to be higher, reaching 34.4°C, compared to the temperature inside the solar panels using cooling which only reaches 30.7°C. The temperature difference between the uncooled solar panel and the cooled solar panel is about 4.3°C, with the light intensity reaching 247.4W/m².

Table 8. Temperature Data at 17.00 pm

	Uncooled						With Cooled					
No	Outside Panel Temperature			In-Panel Temperature			Outside Panel Temperature			In-Panel Temperature		
	Left Section	Center Section	Right Section	Left Section	Center Section	Right Section	Left Section	Center Section	Right Section	Left Section	Center Section	Right Section
1	37,5	37,5	38,3	42,3	43,3	42,9	38,9	40,1	40,3	39,6	39,8	38,8
2	38,1	37,3	37,2	42,5	42,1	42,7	38,8	41,8	42,1	37,6	39,3	38,9
3	37,2	38,8	37,8	43,7	42,4	43,9	39,4	40,9	38,8	39,4	38,1	37,1
Avg.	37,6	37,9	37,8	42,8	42,6	43,2	39,0	40,9	40,0	38,9	39,1	38,3
Total	37,7			42,9			40,1			38,7		
Temperature	40,3						39,4					

Then from the second data above, it can be seen that there is a significant difference between the average temperature inside the solar panels in solar panels using solid salt hydrate coolers and heatsinks and the temperature inside solar panels without coolers. The temperature inside the solar panels without cooling tends to be higher, reaching 42.9°C, compared to the temperature inside the solar panels using cooling which only reaches 38.7°C. The temperature difference between the uncooled solar panel and the cooled solar panel is about 4.2°C, with the light intensity reaching 733.8 W/m².

3.2.2 Effect of Temperature on Current

Table 9. Effect of Temperature on Current

Temperature			**Isc**	
Time (West Indonesia Time)	**With Solid Hydrate Salt Cooler and Heatsink**	**Uncooled**	**With Solid Hydrate Salt Cooler and Heatsink**	**Uncooled**
9:00	41.5	43.4	3.1	2.3
10:00	42.6	45.0	3.8	3.1
11:00	50.4	50.0	4.2	2.2
12:00	41.8	42.6	4.5	3.4
13:00	38.0	38.9	4.4	3.7
14:00	39.7	44.9	4.5	3.8

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15:00	50.6	51.5	4.5	3.9
16:00	41.6	42.6	2.2	1.1
17:00	37.0	37.9	2.7	1.7

To analyze the hourly temperature and current data, we can calculate the current efficiency from 09:00 to 17:00, in the condition with cooling and without cooling. For example, here is the analysis at 09:00 using the formula:

$$\eta = \frac{(3,1-2,3)}{2,3} \times 100\%$$
$$\eta = \frac{0,8}{2,3} \times 100\%$$
$$\eta = 0,34 \times 100\%$$
$$\eta = 34\%$$

3.2.3 Effect of Temperature on Voltage

Table 10. Effect of Temperature on Voltage

Temperature			Voc	
Time (West Indonesia Time)	**With Solid Hydrate Salt Cooler and Heatsink**	**Uncooled**	**With Solid Hydrate Salt Cooler and Heatsink**	**Uncooled**
9:00	41.5	43.4	21,20	19,80
10:00	42.6	45.0	21,20	20,50
11:00	50.4	50.0	20,50	18,50
12:00	41.8	42.6	21,30	19,20
13:00	38.0	38.9	21,50	20,15
14:00	39.7	44.9	22,50	21,50
15:00	50.6	51.5	22,70	21,50
16:00	41.6	42.6	21,50	19,40
17:00	37.0	37.9	20,60	19,40

To analyze the hourly temperature and voltage data, we can calculate the voltage efficiency from 09:00 to 17:00, in the condition with cooling and without cooling. For example, here is the analysis at 09:00 using the formula:

$$\eta = \frac{(21,60-20,50)}{20,50} \times 100\%$$
$$\eta = \frac{1,1}{20,50} \times 100\%$$
$$\eta = 0,05 \times 100\%$$
$$\eta = 5\%$$

3.2.4 Effect of Temperature on Solar Panel Power

The performance of the solar panels with and without solid salt hydrate coolers and heatsinks, showed a significant improvement in the cooled solar panels. With an average power of 81.25 Watts, the cooled solar panels produced 44.4% more power than the panels without coolant (56.26 Watts). This power increase was consistent throughout the day, ranging from 24.19% to 112.45%, with the highest effectiveness at high temperatures, reaching 112.45% at 11am and 111.10% at 4pm. These results confirm the importance of cooling to maintain optimal performance of solar panels, especially in tropical climates. This study concludes that solid salt hydrate coolers and heatsinks are effective solutions to improve the efficiency and productivity of solar panels.

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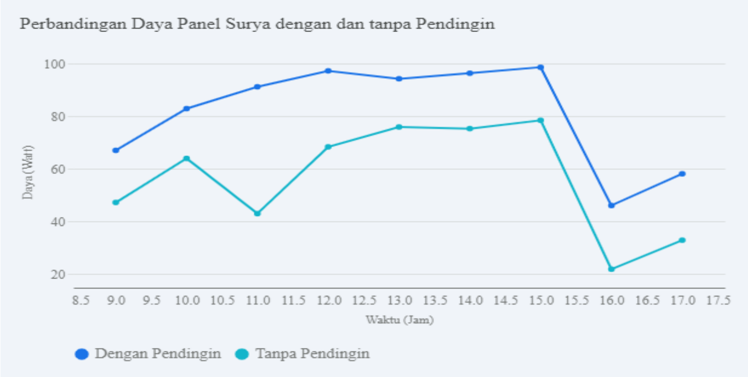

Figure 3. Second Day Temperature to Power Efficiency Graph

4. CONCLUSION

The use of coolants, particularly salt hydrate, significantly increased the capacity of the solar panels. The data shows that in the presence of coolant, the capacity of solar panels increased by an average of 35.25% on the first day and 44.42% on the second day at 15:00 WIB. This increase demonstrates the effectiveness of the cooling in improving the performance of the solar panels. In addition, the decrease in temperature produced by the coolant has a direct impact on improving the efficiency of the solar panels. The lower temperature helps maintain efficiency, which in turn increases the power generated by the solar panel. Thus, the use of coolant not only lowers the temperature but also increases the power output through its effect on the temperature of the solar panel.

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