International Journal of Frontier Technology and Engineering (IJFTE)
Vol. 02, No. 02, June 2024, pp. 52-64
ISSN: 2986-9064

Analysis of the Effect of Monitoring Tools and Automation of Temperature Control on Static Inverter Panel Power of Railbus Batara Kresna

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Received Date: 02-04-2024 Revised Date: 05-05-2024 Accepted Date: 21-06-2024

Abstract

The Static Inverter Panel is an electrical device that processes electrical energy from the Batara Kresna rail-bus generator to produce the required output for the rail-bus. The static inverter panel often experiences cutoffs due to high panel temperatures caused by uncontrolled air circulation within the panel. The cutoff system prevents the panel from functioning until the temperature drops below the specified limit of approximately ±70°C. The power of the static inverter panel must always be maintained to ensure that the rail-bus electrical system operates optimally. The purpose of this study is to determine the impact of panel temperature and room temperature on the power of the static inverter panel. The research was carried out by creating an automated temperature control system and monitoring system to regulate the temperature of the static inverter panel, preventing cutoffs and optimizing the power of the panel. Data processing was carried out by observing graphs during each test. The results of the study indicate that higher panel temperatures, ranging from 30.8 ° C to 47.6 ° C in the morning and evening, lead to reduced panel power. Furthermore, an increase in room temperature from 31.8 ° C to 38.0 ° C in the morning also results in a decrease in power. However, increasing room temperature from 38.0 ° C to 42.5 ° C in the evening causes irregular power changes. By controlling the panel temperature, the temperature increases become more regulated, thereby optimizing the power output of the static inverter panel.

Keywords : inverter panel, temperature control, power optimization, rail-bus, thermal monitoring

1 Introduction

Trains are public transportation vehicles that convert energy into motion, capable of operating independently or in conjunction with other railway equipment running on tracks. PT Kereta Api Indonesia is a company that manages railway transportation services, including the Batara Kresna Solo rail bus. This train is classified as a KRDE (Diesel Electric Railway) [1], [2], [3], [4]. The diesel engine is used to generate electrical power, which is then processed by a VVVF (Variable Voltage Variable Frequency) system for train propulsion and an SIV (Static Inverter) system to supply 380 V and 220 V electricity for components such as air compressors, air conditioning, and others. If either of these systems malfunctions, the train will not be able to operate until the systems are repaired [5].

According to the damage report for the Batara Kresna rail bus on 10 January 2023, the static inverter panel experienced a cutoff due to excessively high temperatures. This caused the static inverter panel to stop working until the temperature dropped to within the permissible specification limits, which is below ±70°C as per the static inverter guidelines [5], [6], [7]. In addition to this issue, the power of the static inverter panel must be monitored to ensure the optimal performance of the train's electrical system.

Therefore, the purpose of this study is to determine the effect of the temperature of the panel and the temperature of the room on the power generated by the static inverter panel. In addition, this research also produces a monitoring and automation tool for controlling the temperature of the static inverter panel to determine the temperature increase that occurs at panel temperature and room temperature. In addition, with the monitoring and automation of the temperature control that occurs in the static inverter panel, the temperature in the panel will be more controlled and can facilitate mechanics in performing maintenance and repairs.

2 Literature Review

Electrical power is the amount of electrical energy flowing per second, measured in joules per second or watts [6]. Several factors influence the power value in an electrical circuit, such as current, voltage, and resistance. The magnitude of current flow is affected by the resistance in the conductor's conductivity [8], [9]. The temperature in an electrical circuit can affect the resistance in the conductor's conductivity. As the conductor's temperature increases, its resistance also increases. This is due to the increased vibration of free electrons flowing through the conductor. Higher temperatures cause greater electron vibrations within the conductive material. Changes in conductor temperature are influenced by the ambient temperature around the conductor and the load current flowing through the static inverter circuit. The static inverter panel is located in the driver's cabin, so the panel temperature rise can be affected by the cabin's room temperature. Since the room temperature is lower than the panel temperature, air circulation can occur from the room to the panel [10, 11, 12, 13, 14, 15, 16].

The research of Arindrian Kurnia Raharjo and Asrori Asrori (2023), entitled "Analysis of Cooling Temperature Effects on the Charging Process of a Solar-Powered Scooter's Lithium Battery Box," aimed to determine the effect of cooling temperature variations on the charging power of a LiFePO4 e-scooter battery with a solar panel. The research was carried out by developing a battery monitoring and cooling management system to measure and regulate battery temperature using an ESP32 microcontroller. The results of this study showed that the charging power at a temperature of 25°C was 19% higher compared to the charging power at 35°C [17].

The research of Moch. Gembong Abi Rahman and Suwasti Broto (2020), entitled Design of the Temperature and Air Humidity Control System at 20 kV Kubikel Based on the Internet of Things, aims to solve problems that often occur in cubicles, namely the corona. Corona is a phenomenon that occurs when the air around the conductor is ionized. Temperature and humidity data collection is carried out at substations SP13, KJ274, and KJ365. It takes 8 minutes for the humidity to reach 79 % of the initial value of 30 % and 13 minutes for the temperature to reach 49ºC from the initial temperature of 26ºC. In the test, the prototype tool can control the temperature and humidity until below the set point and keep it below the set point, so it can appear corona [18].

3 Method

This research uses experimental research, where the beginning of this research is to create a monitoring and automation tool to control the temperature of the static inverter panel using an ESP32 controller that can be connected to the Blynk application to monitor the temperature of the static inverter panel and room temperature in Railbus Batara Kresna. The static inverter panel temperature control uses a fan cooler, while the temperature reading uses a DHT11 sensor. The current generated by the static inverter panel can be measured using an ampere meter, while the voltage generated by the static inverter panel can be observed through the monitor on the railbus. The data collection process was carried out at the Solo Locomotive Dipo located in Mangkubumen, Banjarsari District, Surakarta City, Central Java.

3.1 Electronic Circuit

This electronic circuit uses the EasyEDA website. It can be observed in Figure 1, the DHT11 sensor signal pin will be connected to pin 2 of ESP32 for the inside temperature reading and pin 4 of ESP32 for the room temperature reading. ESP32 which is a controller to control and regulate the input signal from the DHT11 sensor which will then issue an output for the blynk application and fan cooler. The input voltage source for

ESP32 is 5 V, but because the voltage source is 12 V, the LM2596 stepdown is used to reduce the voltage. The output of the stepdown will be connected to the Vin (positive) and Gnd (negative) pins. When ESP32 produces a signal output from ESP32 connected to the relay, so that the fan cooler can operate automatically according to the program on ESP32. Pin 12 is connected to the first fan cooler relay, pin 13 is connected to the second fan cooler relay, while pin 14 is connected to the third fan cooler relay. Figure 1 is an electronic circuit of the Batara Kresna Railbus SIV Panel Temperature Control Monitoring and Automation Tool.

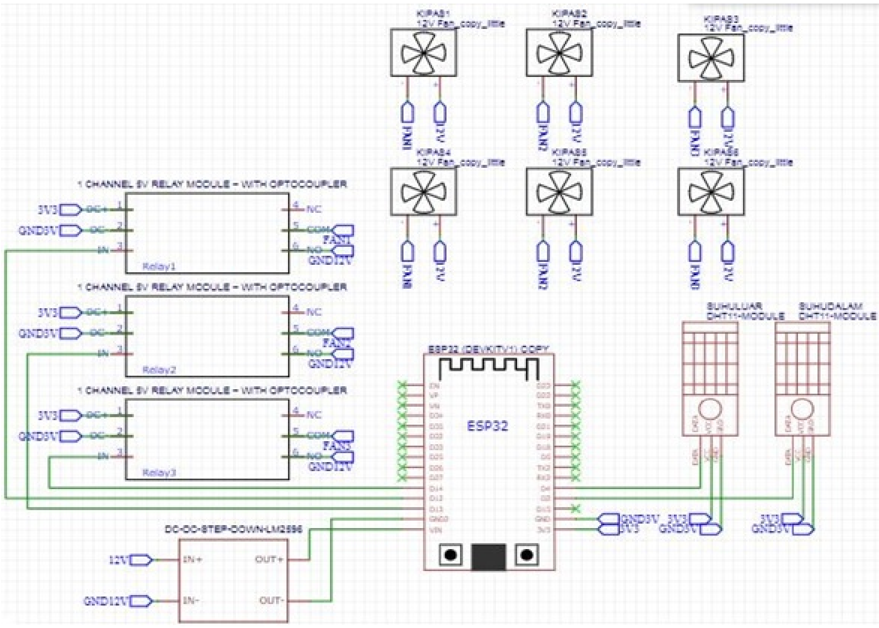


Figure 1: The Electronic Circuit

3.2 Static Inverter Panel Temperature Control Monitoring and Automation Tool

Making ESP32-based tools with a series of DHT11 sensors, such as panel temperature readers and room temperature, which will then be processed by ESP32 to produce temperature readings through the Blynk application as in Figure 2. In addition, the fan cooler will be active according to the temperature conditions of the static inverter panel that has been programmed in ESP32 as in Figure 3. The results of the monitoring and automation of the static inverter panel temperature control as shown in Figure 2 and 3.

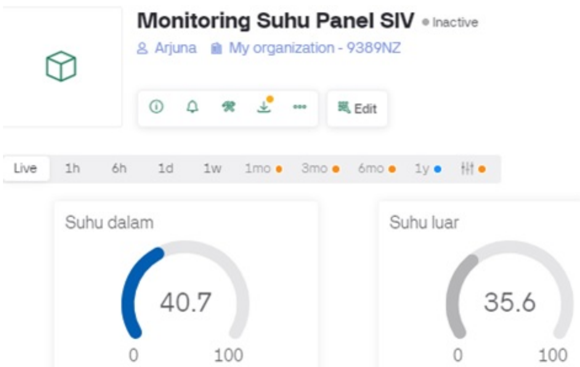


Figure 2: Panel Temperature and Room Temperature Monitoring Display

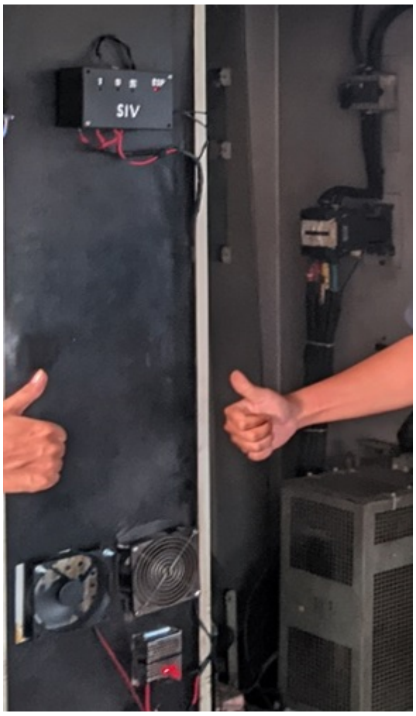


Figure 3: Static Inverter Panel Temperature Control Monitoring and Automation Tool

3.3 Static Inverter Panel

The Static Inverter panel on the Rail-bus Batara Kresna is an electronic device that converts the direct current power of 560-660 VAC from the generator into a 3-phase current power of 380 VAC, as shown in Figure 4. In contrast to mechanical inverters, static inverters have no moving parts, such as rotating switches or mechanical contacts. Instead, these static inverters use electronic components such as transistors and other semiconductor devices to achieve the conversion process. The SIV on Rail-bus is used as an Auxiliary Load supplier which has a stable frequency, used for AC compressors, power sockets, and other loads. The SIV used for auxiliary has a stable frequency of 50 Hz, and 220 VAC load power will be reduced using a transformer on the panel as a supplier of cabin lights, passenger lights, and other loads [5].

3.4 Experimental Setup

The last stage before collecting the data is to prepare all tools and materials according to Figure 5. In this test, the static inverter panel will produce current and voltage. For current readings, using an ampere meter while reading the voltage through the train monitor. Panel temperature and room temperature readings use the blynk application which can be monitored online and in real time. The tests were carried out in the morning and evening with conditions without temperature control automation tools and with temperature control automation tools to compare these two conditions.

Data collection was carried out six times, namely three times without a static inverter panel temperature control automation tool and three times with a static inverter panel temperature control automation tool. The data collection process is carried out by recording data on panel temperature, room temperature, current, voltage, and power generated by the static inverter panel according to the test time.

4 Results and Discussion

The results of the study were obtained by reading the panel temperature and room temperature through the blynk application, but also reading the current contained in the Ampere Meter and then getting the power results. There are two test conditions, namely conditions without a static inverter panel temperature control

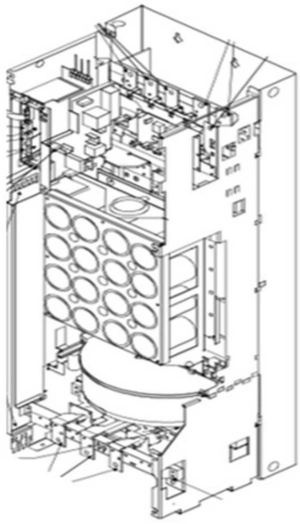


Figure 4: Static Inverter Panel

automation tool and with a static inverter panel temperature control automation tool. The results of the research data can be seen in the explanation below.

4.1 Test Data Without Static Inverter Panel Temperature Control Automation Device

The following is a table of research data without the SIV Panel Temperature Control Tool, that is, the first test can be seen in Table 1, the second test can be seen in Table 2 and the third test can be seen in Table 3 below:

Table 1: Measurement result for Day 1 without devices

Morning

No	Time	Panel Temp. (°C)	Room Temp. (°C)	Current (A)	Voltage (V)	Power (W)
1	09:00	33.3	32.8	13.3	380	8043.9
2	09:10	34.7	33.8	13.1	380	7923
3	09:20	35.6	33.8	12.4	380	7499.6
4	09:30	36.9	33.8	12.0	380	7257.7
5	09:40	38.0	33.8	11.7	380	7076.3
6	09:50	39.0	34.7	11.5	380	6955.3

Afternoon

No	Time	Panel Temp. (°C)	Room Temp. (°C)	Current (A)	Voltage (V)	Power (W)
1	15:01	44.8	41.6	12.2	380	7378.7
2	15:11	45.3	40.6	12.2	380	7378.7
3	15:21	45.7	42.5	12.0	380	7257.7
4	15:31	47.0	41.1	11.8	380	7136.7
5	15:41	47.1	40.1	11.5	380	6955.3
6	15:51	47.6	40.6	10.9	380	6592.4

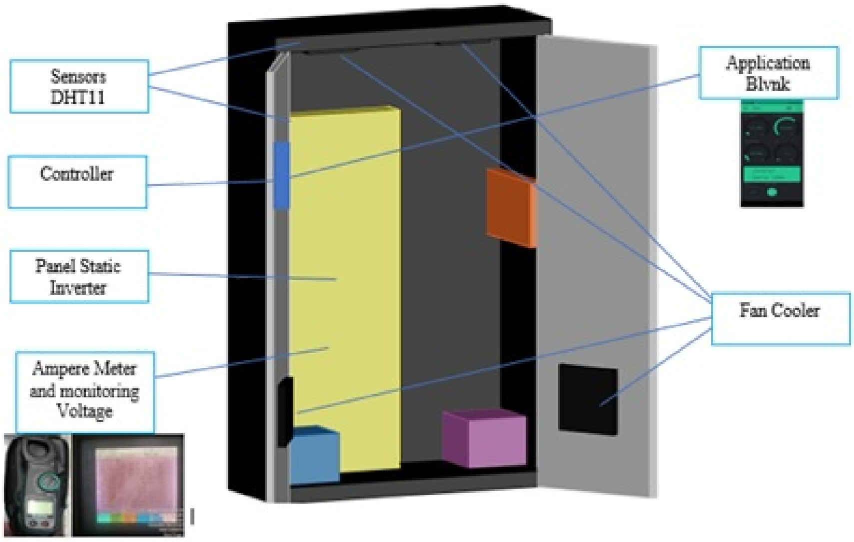


Figure 5: Experimental Setup

Table 2: Measurement result for Day 2 without devices

Morning

No	Time	Panel Temp. (°C)	Room Temp. (°C)	Current (A)	Voltage (V)	Power (W)
1	08:50	33.3	32.3	13.3	380	8043.9
2	09:10	34.7	32.8	13.0	380	7862.5
3	09:20	35.6	33.8	12.8	380	7741.5
4	09:30	36.9	33.3	12.3	380	7439.1
5	09:40	38.0	34.7	11.5	380	6955.3
6	09:50	39.0	33.8	11.4	380	6894.8

Afternoon

No	Time	Panel Temp. (°C)	Room Temp. (°C)	Current (A)	Voltage (V)	Power (W)
1	15:00	43.9	42.0	12.5	380	7560.1
2	15:10	44.4	40.6	12.3	380	7439.1
3	15:20	44.5	39.5	11.8	380	7136.7
4	15:30	45.3	42.0	11.5	380	6955.3
5	15:40	45.7	39.5	11.3	380	6834.3
6	15:50	45.7	39.5	11.1	380	6713.4

Table 1, Table 2 and Table 3 show the results of research without the use of temperature control automation tools, showing the increase in panel temperature cannot be controlled properly. The temperature of the room affects the increase in the temperature of the panel. In addition, it can be seen in Tables 1, Table 2, and Table 3 that the greater the panel temperature, the smaller the current value (ampere) and power (watt) of the SIV panel. The higher the room temperature in the morning, the smaller the power of the SIV panel, but the higher the room temperature in the afternoon shows different changes in the power (wattage) of the SIV panel.

The data show that the panel temperature and room temperature increase throughout the day, reaching a peak in the afternoon. As temperatures rise, the current output gradually decreases, resulting in a reduction in power generation. This indicates a negative correlation between temperature and current, which affects the overall power output. Despite consistent voltage (380 V), power drops significantly, especially in the afternoon,

Table 3: Measurement result for Day 3 without devices

Morning

No	Time	Panel Temp. (°C)	Room Temp. (°C)	Current (A)	Voltage (V)	Power (W)
1	09:03	33.8	32.8	13.3	380	8043.9
2	09:13	35.2	33.8	12.9	380	7802.0
3	09:23	36.3	34.0	11.6	380	7015.8
4	09:33	37.4	34.2	11.3	380	6834.3
5	09:43	38.5	34.4	11.5	380	6955.3
6	09:53	39.0	35.6	11.4	380	6894.8

Afternoon

No	Time	Panel Temp. (°C)	Room Temp. (°C)	Current (A)	Voltage (V)	Power (W)
1	15:00	44.8	41.2	12.0	380	7257.7
2	15:10	45.3	40.1	11.7	380	7076.3
3	15:20	45.8	42.1	11.6	380	7015.8
4	15:30	47.1	40.6	11.4	380	6894.8
5	15:40	47.2	39.0	11.0	380	6652.9
6	15:50	47.6	40.1	10.6	380	6411.0

with the lowest value recorded at 6411.0 W. Temperature management is crucial to optimize the efficiency of solar panels.

4.2 Test Data with Static Inverter Panel Temperature Control Automation Device

The following is a table of research data with the SIV Panel Temperature Control Tool, namely the Fourth Test can be seen in Table 4, the Fifth Test can be seen in Table 5, and the sixth test can be seen in Table 6 below:

Table 4: Measurement result for Day 4 with devices

Morning

No	Time	Panel Temp. (°C)	Room Temp. (°C)	Current (A)	Voltage (V)	Power (W)
1	08:50	30.8	31.8	14.3	380	8648.8
2	09:10	32.8	32.3	13.5	380	8164.9
3	09:20	33.8	33.8	12.8	380	7741.5
4	09:30	35.2	34.7	12.6	380	7620.6
5	09:40	36.3	35.6	12.4	380	7499.6
6	09:50	36.9	35.6	12.0	380	7257.7

Afternoon

No	Time	Panel Temp. (°C)	Room Temp. (°C)	Current (A)	Voltage (V)	Power (W)
1	15:00	40.6	38.5	12.8	380	7741.5
2	15:10	41.1	38.0	12.5	380	7560.1
3	15:20	41.6	40.1	12.2	380	7378.7
4	15:30	42.0	39.1	11.7	380	7076.3
5	15:40	42.0	38.5	11.8	380	7136.7
6	15:50	42.1	39.0	11.6	380	7015.8

Tables 4, Table 5, and Table 6 show the results of the study using a temperature control automation device, so that the panel temperature increase can be controlled properly. Although the panel temperature is affected by room temperature, the increase in panel temperature is not too significant compared to the increase in panel temperature without using a temperature control automation tool. It can be seen in Table 4 Table 5 and Table 6 that the same conditions occur when the higher the panel temperature, the lower the current value (ampere), but the decrease in current value is not so large compared to conditions without using a temperature control automation tool. With a decrease in current value that is not so large, the decrease in power (wattage) of the SIV panel is also not so large. Similarly to test conditions without using the tool, the greater the panel temperature, the smaller the SIV panel power. Although the higher the room temperature in the morning conditions, the smaller the power will be, but the higher the room temperature in the afternoon shows different changes in the power (wattage) of the SIV panel.

Table 5: Measurement result for Day 5 with devices

Morning

No	Time	Panel Temp. (°C)	Room Temp. (°C)	Current (A)	Voltage (V)	Power (W)
1	09:00	33.3	33.8	13.2	380	7983.5
2	09:10	34.2	34.2	13.1	380	7923.0
3	09:20	35.2	35.2	12.9	380	7802.0
4	09:30	36.8	36.3	12.4	380	7499.6
5	09:40	37.5	36.9	12.0	380	7257.7
6	09:50	38.5	38.0	12.0	380	7257.7

Afternoon

No	Time	Panel Temp. (°C)	Room Temp. (°C)	Current (A)	Voltage (V)	Power (W)
1	15:01	41.6	41.1	12.5	380	7560.1
2	15:11	42.0	41.1	12.6	380	7620.6
3	15:21	42.5	41.1	12.1	380	7318.2
4	15:31	43.0	40.6	11.8	380	7136.7
5	15:41	43.0	39.5	11.7	380	7076.3
6	15:51	43.0	39.0	11.5	380	6955.3

Table 6: Measurement result for Day 6 with devices

Morning

No	Time	Panel Temp. (°C)	Room Temp. (°C)	Current (A)	Voltage (V)	Power (W)
1	09:05	31.8	31.8	14.0	380	8467.3
2	09:15	33.3	33.3	13.4	380	8104.4
3	09:25	34.6	33.3	12.9	380	7802.0
4	09:35	35.6	34.7	12.4	380	7499.6
5	09:45	36.9	35.6	12.5	380	7560.1
6	09:55	37.4	34.7	12.2	380	7378.7

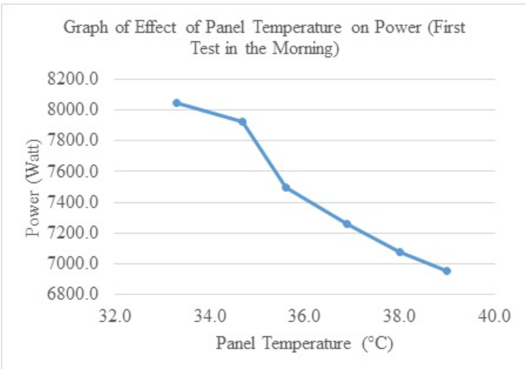
Afternoon

No	Time	Panel Temp. (°C)	Room Temp. (°C)	Current (A)	Voltage (V)	Power (W)
1	15:00	38.6	–	13.0	380	7862.5
2	15:10	38.0	–	12.7	380	7681.1
3	15:20	40.1	–	12.5	380	7560.1
4	15:30	39.0	–	12.0	380	7257.7
5	15:40	38.5	–	11.7	380	7076.3
6	15:50	38.6	–	11.5	380	6955.3

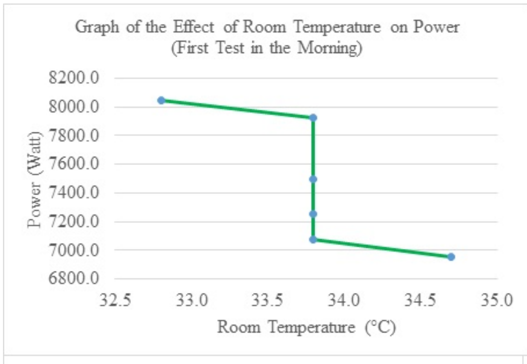
Data collected on days 4, 5 and 6 reveal a consistent trend of increasing panel and room temperatures throughout the morning and afternoon, with higher afternoon temperatures. Power output decreases as the panel temperature increases, probably because of the reduced photovoltaic efficiency at higher temperatures. Morning measurements exhibit higher currents and power compared to afternoon measurements, suggesting that optimal energy generation occurs in cooler conditions. The voltage remains constant at 380V across all measurements, highlighting current variations as the primary factor influencing power output. This highlights the importance of maintaining the temperature of the panel to maximize energy efficiency in solar power systems.

4.3 Relationship Between Panel Temperature, Room Temperature, and Power Output

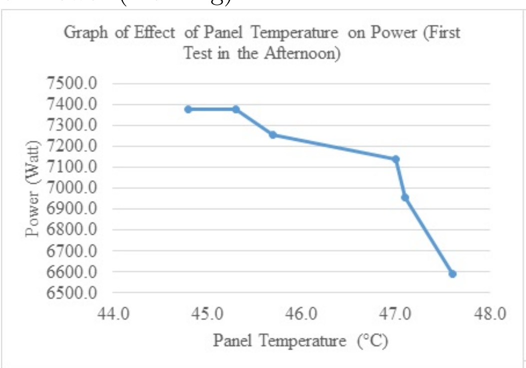
Figure 6 is the first test graph showing the effect of changes in the panel temperature and room temperature on the power of the SIV panel in the morning and afternoon without the automation tool of the temperature control of the SIV panel. The higher the panel temperature, the lower the power value (wattage) of the SIV panel. The higher the room temperature in the morning, the power will decrease, but the higher the room temperature in the afternoon, it shows different power changes. Figure 6a is a graph of the effect of panel temperature on power in the morning. Figure 6b is a graph of the effect of room temperature on power in the morning. Figure 6c is a graph of the effect of panel temperature on power in the afternoon. Figure 6d is a graph of the effect of room temperature on power in the afternoon.



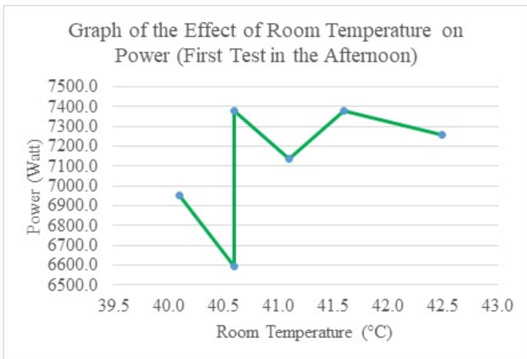
(a) Graph of the Effect of Panel Temperature on Power (morning)



(b) Graph of the Effect of Room Temperature on Power (morning)



(c) Graph of the Effect of Panel Temperature on Power (afternoon)



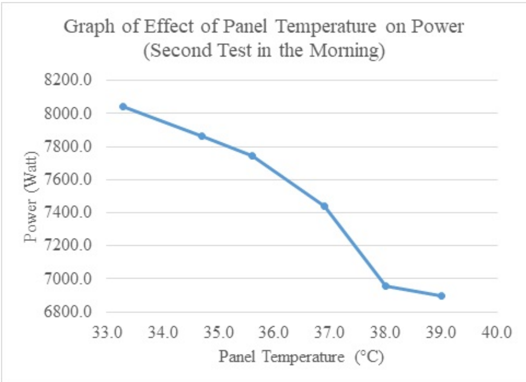
(d) Graph of the Effect of Room Temperature on Power (afternoon)

Figure 6: Graphical Representation of the Effect of Panel Temperature and Room Temperature on Power (First Test)

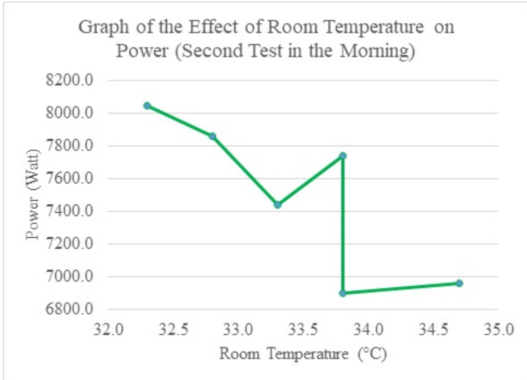
Figures 7a to 7d illustrate the impact of room and panel temperatures on inverter power output during the second test, conducted in the morning and afternoon. In the afternoon, the power output increases with room temperature, reaching a peak of 41.5 ° C before falling sharply at 42.5 ° C. This suggests an optimal range for room temperature. In contrast, the panel temperature shows a clear negative correlation with power; As the panel temperature rises from 43.5 ° C to 46 ° C, the power output consistently decreases.

In the morning, the relationship between room temperature and power output is less consistent, with a significant drop at 33 ° C followed by a slight recovery at 34 ° C. However, the effect of panel temperature mirrors the trend in the afternoon, with power output steadily decreasing as the panel temperature increases from 33 ° C to 39 ° C.

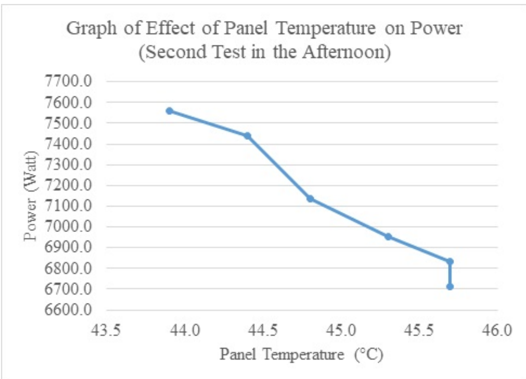
Overall, the findings indicate that higher panel temperatures reduce inverter efficiency, while room-temperature effects are less straightforward but still influential at extreme levels. Effective cooling is vital to maintain performance.



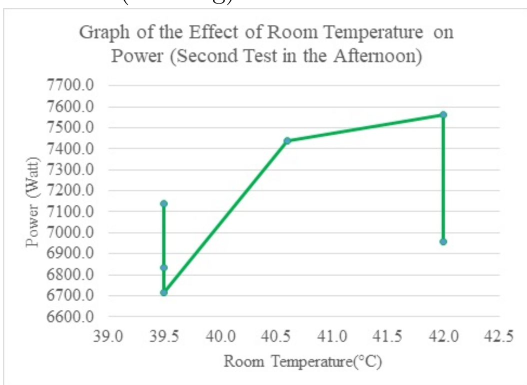
(a) Graph of the Effect of Panel Temperature on Power (morning)



(b) Graph of the Effect of Room Temperature on Power (morning)



(c) Graph of the Effect of Panel Temperature on Power (afternoon)



(d) Graph of the Effect of Room Temperature on Power (afternoon)

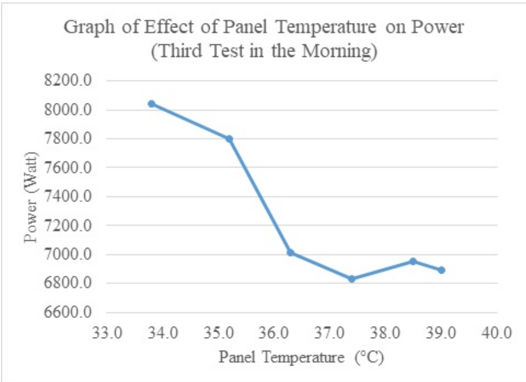
Figure 7: Graphical Representation of the Effect of Panel Temperature and Room Temperature on Power (Second Test)

Figure 8 represents the results of the third experiment conducted to assess the consistency of the relationship between panel and room temperatures and the power output of the inverter. This experiment follows the same methodology as the two previous tests, ensuring comparable conditions and outcomes.

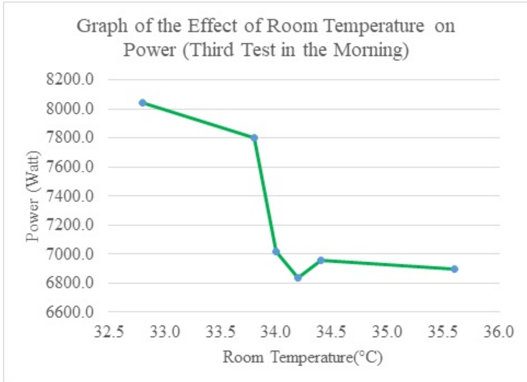
As observed in the previous experiments, the third test reaffirms the inverse relationship between panel temperature and power output. As the panel temperature increases, the power output decreases consistently, indicating the critical impact of the panel temperature on inverter performance. The consistency across all three experiments highlights the reliability of this trend, demonstrating that higher panel temperatures consistently lead to reduced efficiency.

The effect of room temperature, on the other hand, shows some variability but still influences power output. The results suggest that while room temperature indirectly impacts performance, likely through its effect on panel cooling, its role is less dominant than that of panel temperature. However, extreme room temperatures, whether high or low, can still disrupt performance, further emphasizing the need for controlled environmental conditions.

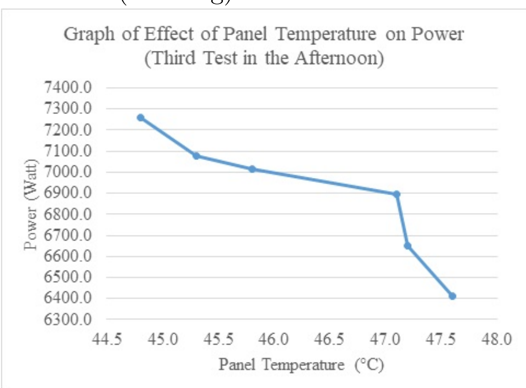
By using a consistent testing method across all three experiments, this study validates the trends observed and confirms the critical importance of thermal management. Proper cooling mechanisms for the panels and maintaining stable room temperatures are essential strategies for optimizing inverter efficiency and ensuring consistent performance across different operating conditions.



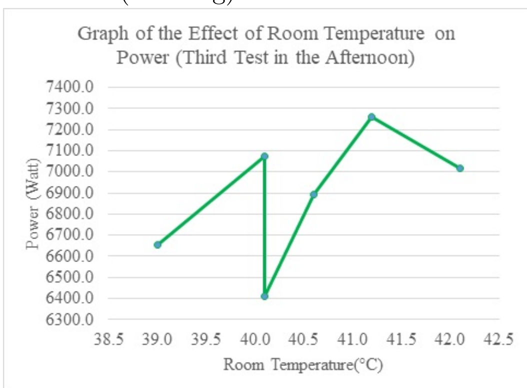
(a) Graph of the Effect of Panel Temperature on Power (morning)



(b) Graph of the Effect of Room Temperature on Power (morning)



(c) Graph of the Effect of Panel Temperature on Power (afternoon)



(d) Graph of the Effect of Room Temperature on Power (afternoon)

Figure 8: Graphical Representation of the Effect of Panel Temperature and Room Temperature on Power (Third Test)

Figures 6 to 8 illustrate the relationship between room temperature, panel temperature, and power output of an inverter in three test sessions conducted in the morning and afternoon. A clear trend emerges where the panel temperature consistently shows an inverse relationship with power output. As the panel temperature rises, the power output gradually decreases in all tests, regardless of the time of day. This consistency highlights the critical role of the panel temperature in determining the inverter efficiency.

In contrast, the impact of room temperature on power output is less predictable. In some instances, power output increases with rising room temperature, peaking at specific ranges before declining. For example, in the afternoon tests, power output generally improves with higher room temperatures, reaching an optimum point before dropping at extreme levels. However, during morning tests, the relationship fluctuates, with irregular patterns that suggest a less direct or stable effect of room temperature on performance. This inconsistency can be attributed to other factors, such as initial heating or ambient thermal equilibrium during the tests.

In general, panel temperature has a more significant and consistent effect compared to room temperature. Higher panel temperatures result in a steady decrease in power, highlighting the need for effective thermal management at the panel level. Room temperature, while less critical, may still indirectly influence performance by affecting the cooling efficiency of the system or the ambient conditions surrounding the panel.

Interestingly, the afternoon tests generally show lower power outputs compared to the morning tests. This difference could be due to higher ambient temperatures in the afternoon, leading to higher panel temperatures and higher thermal stress on the system. Furthermore, extreme temperature ranges—whether in the panel or in the room—consistently degrade the performance of the inverter, underscoring the importance of maintaining moderate operating conditions. Efficient cooling mechanisms and thermal regulation are essential to optimize inverter performance and reliability under varying conditions.

5 Conclusion

The study, titled "Analysis of the Effect of Monitoring Tools and Automation of Temperature Control on Static Inverter Panel Power of Rail-bus Batara Kresna," investigates the impact of temperature on inverter performance and the potential benefits of monitoring and automation for temperature regulation. The experiments reveal a consistent inverse relationship between panel temperature and power output. Higher panel temperatures lead to a steady decrease in power, highlighting the importance of precise thermal management to maintain inverter efficiency.

The influence of room temperature, while less consistent, still plays a significant role, indirectly affecting the panel's cooling efficiency. Power output generally increases with room temperature to an optimum point before declining to extreme levels. This suggests that automation of temperature control could stabilize performance by preventing overheating or excessive cooling.

Afternoon tests consistently showed lower power outputs compared to morning tests, probably due to higher ambient temperatures that cause thermal stress. These findings highlight the critical need for automated systems to monitor and regulate temperature conditions in real time. By employing effective cooling mechanisms and room temperature management, such systems can optimize inverter efficiency and ensure stable performance.

In conclusion, the integration of monitoring tools and automated temperature control systems for the Rail-bus Batara Kresna can significantly enhance the reliability and efficiency of its static inverter panels. Implementing these measures will help address temperature-related challenges and support long-term operational stability.

References

[1] A. García-Garre and A. Gabaldón, "Analysis, evaluation and simulation of railway diesel-electric and hybrid units as distributed energy resources," *Applied Sciences*, vol. 9, no. 17, 2019. [Online]. Available: https://www.mdpi.com/2076-3417/9/17/3605

[2] M. Kapetanović, A. Núñez, N. van Oort, and R. M. Goverde, "Reducing fuel consumption and related emissions through optimal sizing of energy storage systems for diesel-electric trains," *Applied Energy*, vol. 294, p. 117018, 2021. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0306261921004840

[3] M. Kapetanović, M. Vajihi, and R. M. P. Goverde, "Analysis of hybrid and plug-in hybrid alternative propulsion systems for regional diesel-electric multiple unit trains," *Energies*, vol. 14, no. 18, 2021. [Online]. Available: https://www.mdpi.com/1996-1073/14/18/5920

[4] M. Jabłoński and P. Borkowski, "Correction mechanism for balancing driving torques in an opencast mining stacker with an induction motor and converter drive system," *Energies*, vol. 15, no. 4, 2022. [Online]. Available: https://www.mdpi.com/1996-1073/15/4/1282

[5] K. T. Pambudi and E. Firmansyah, "Busbar study regarding stray inductance of a 50kw 600v three-phase static inverter for railway applications," in *2023 10th International Conference on Information Technology, Computer, and Electrical Engineering (ICITACEE)*, 2023, pp. 116–120.

[6] X. Huang, Q. Liao, Q. Li, S. Tang, and K. Sun, "Power management in co-phase traction power supply system with super capacitor energy storage for electrified railways," *Railway Engineering Science*, vol. 28, no. 1, pp. 85–96, Mar 2020. [Online]. Available: https://doi.org/10.1007/s40534-020-00206-x

[7] F. Stella, G. Pellegrino, and E. Armando, "Three-phase inverter for formula sae electric with online junction temperature estimation of all sic mosfets," in *2020 IEEE Applied Power Electronics Conference and Exposition (APEC)*, 2020, pp. 1154–1161.

[8] M. Al-Badri, P. Pillay, and P. Angers, "A formula for class f induction motor specified temperature," in *2021 IEEE 12th Energy Conversion Congress Exposition - Asia (ECCE-Asia)*, 2021, pp. 2110–2114.

[9] S. Wang, P. Takyi-Aninakwa, S. Jin, C. Yu, C. Fernandez, and D.-I. Stroe, "An improved feedforward-long short-term memory modeling method for the whole-life-cycle state of charge prediction of lithium-ion batteries considering current-voltage-temperature variation," *Energy*, vol. 254, p. 124224, 2022. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0360544222011276

[10] Z. He, Y. Yan, and Z. Zhang, "Thermal management and temperature uniformity enhancement of electronic devices by micro heat sinks: A review," *Energy*, vol. 216, p. 119223, 2021. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0360544220323306

[11] W.-B. Zhu, S.-S. Xue, H. Zhang, Y.-Y. Wang, P. Huang, Z.-H. Tang, Y.-Q. Li, and S.-Y. Fu, "Direct ink writing of a graphene/cnt/silicone composite strain sensor with a near-zero temperature coefficient of resistance," *J. Mater. Chem. C*, vol. 10, pp. 8226–8233, 2022. [Online]. Available: http://dx.doi.org/10.1039/D2TC00918H

[12] D. Gall, "The search for the most conductive metal for narrow interconnect lines," *Journal of Applied Physics*, vol. 127, no. 5, p. 050901, 02 2020. [Online]. Available: https://doi.org/10.1063/1.5133671

[13] A. Francis, D. Abraimov, Y. Viouchkov, Y. Su, F. Kametani, and D. C. Larbalestier, "Development of general expressions for the temperature and magnetic field dependence of the critical current density in coated conductors with variable properties," *Superconductor Science and Technology*, vol. 33, no. 4, p. 044011, feb 2020. [Online]. Available: https://dx.doi.org/10.1088/1361-6668/ab73ee

[14] Y. Al-Wreikat, C. Serrano, and J. R. Sodré, "Effects of ambient temperature and trip characteristics on the energy consumption of an electric vehicle," *Energy*, vol. 238, p. 122028, 2022. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0360544221022763

[15] P. Chystiakov, O. Chornyi, B. Zhautikov, and G. Sivyakova, "Remote control of electromechanical systems based on computer simulators," in *2017 International Conference on Modern Electrical and Energy Systems (MEES)*, 2017, pp. 364–367.

[16] Q. Iqbal, S. Fang, Y. Zhao, Y. Yao, Z. Xu, H. Gan, H. Zhang, L. Qiu, C. N. Markides, and K. Wang, "Thermo-economic assessment of sub-ambient temperature pumped-thermal electricity storage integrated with external heat sources," *Energy Conversion and Management*, vol. 285, p. 116987, 2023. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0196890423003333

[17] A. Kurnia and A. Asrori, "Analysis of the effect of cooling temperature in lithium-battery box in charging process in solar scooter," *Scientific Journal of Mechanical Engineering Kinematika*, vol. 8, no. 2, pp. 109–118, Dec 2023. [Online]. Available: https://kinematika.ulm.ac.id/index.php/kinematika/article/view/264

[18] M. G. A. Rahman and S. Broto, "Design of temperature and air humidity control system on 20kv cubicle based on internet of things (iot)," *MAESTRO*, vol. 3, no. 2, pp. 440–450, 2020. [Online]. Available: https://jom.ft.budiluhur.ac.id/index.php/maestro/article/view/419