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Implementation of Solar Panels as an Alternative to Electric Power Used in WiFi-based Freezer Box Temperature Monitoring System (Case Study of NN Frozen Food Wajak)

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ABSTRACT

A freezer box temperature monitoring system using solar panels as alternative power is an important technology to ensure the quality of stored products. This research develops a WiFi-based temperature monitoring system that uses a DS18B20 temperature sensor, a PZEM-004T digital sensor, and an ESP8266 module to read and send real-time data to a website platform. Data is collected through a temperature sensor connected to the ESP8266 microcontroller, then displayed on the LCD screen and uploaded to the server for further monitoring via WiFi connection. The results show that this system successfully maintains the freezer box temperature at optimal conditions with an average temperature value of -24.82°C and a temperature range ranging from -28.81°C to -19.63°C. The voltage values are in the range of 197.10 V - 218.70 V, current between 0.02 A - 1.03 A, and power between 158 W - 186.80 W.

Keywords: *Freezer Box, Solar Panel, Temperature Sensor DS18B20, Microcontroller ESP8266*

1. INTRODUCTION

Electrical energy is a very important energy for human life on earth. Electrical energy acts as a resource for technology and various electrical devices made by humans. Human dependence on electrical energy eventually has an impact on its availability which is starting to be limited and depleted. Actions that can be taken to prevent the depletion of energy resources are by saving using alternative and renewable energy resources such as solar panels.

The use of solar panels as a renewable energy source is becoming increasingly important as part of efforts to reduce dependence on fossil fuels and cut greenhouse gas emissions. Solar panels have several advantages, including an unlimited and non-polluting source of energy, flexibility in applications from small-scale, such as portable devices, to large-scale power plants, and low maintenance costs once installed. However, the challenges in developing and applying this technology are also relatively large. The energy conversion efficiency of solar panels varies, and other factors such as sunlight intensity, temperature and panel orientation can affect performance. In addition, large-scale installation is still an obstacle to the use of solar panels, as the need for a large surface area must be carefully considered.

From the description above, the plan is to build a "Wireless-based Freezer Box Temperature and Humidity Monitoring System and Implementation of Solar Panels as an Alternative to the Electric Power Used" based on a case study at MSME Partner NN Frozen Food Wajak. The system uses a DS18B20 temperature sensor placed inside the freezer box and a PZEM-004T digital sensor to measure conditions periodically. The data collected by the sensor will be read by the microcontroller, here using ESP8266. The microcontroller sends the data wirelessly through the ESP8266 module to the monitoring centre, which is a website. The solar panel is used as an alternative power for the freezer box so that when there is a power outage, the freezer box remains on and the quality of the frozen food product is maintained. Thus, this system ensures that the freezer box remains at maximum condition, while the implementation of solar panels as alternative power improves energy efficiency and sustainability.

2. LITERATURE REVIEW

Previous research is one of the references in making research, so that the author can add the theory used in examining the research carried out. This research is not the first time, but has been done by several experts. Below are some research journals as references that have been done before.

2.1 First Literature

Research by Komang Dody Indra Jaya, I Gede Dyana Arjana, and I Made Suartika with the title "Rancang Bangun Sistem Kontrol dan Monitoring Suhu pada Ruang Freezer Berbasis ESP8266 (Studi Kasus Pada PT. Aerofood ASC Denpasar)". The problem raised in this research is how to make a temperature control and monitoring system in an IoT-based freezer room using Wemos D1 R2. This research involves a case study at PT Aerofood ACS Denpasar which was conducted from December 2022 to March 2023. In this study, prototype testing in the freezer room took place from 27/2/2023 - 6/3/2023 producing 168 data. During the test, the DHT22 sensor recorded the lowest temperature of –23.91°C and the highest temperature reached –16.63°C, with an average temperature of –22.57°C. Meanwhile, the lowest humidity recorded by the DHT22 sensor was 72.48% and the highest humidity reached 96% with an average humidity of 75.38%.

2.2 Second Literature

Research by Kevin Christian, Silvia Rostianingsih, and Resmana Lim with the title "Alarm Sensor Temperatur untuk Ruang Pendingin Menggunakan IoT". This research is based on the researcher's desire to help facilitate the monitoring of the condition of the cooling room by showing the room temperature in the application. The application will also send a notification in the form of an alarm if the room temperature rises or falls beyond a predetermined limit. Tests carried out on 2 cooling rooms were carried out by monitoring 4 different points. The result data obtained is influenced by how often the cooling room is opened and closed to take or put items, the number of items stored, and the temperature setting of the cooling room from the electrical panel.

2.3 Third Literature

Research by B Padmaja, Vijayakumar Ch, E Krishna Rao Patro, and B Shashirekha with the title "A Smart IoT System for Remote Refrigeration Monitoring". The field of refrigeration industry has marked its significance for storing food and beverages. Cold warehouses are widely used to store various combinations of large quantities of fresh food stocks at suitable temperatures to maintain their quality. Any deviation from this favourable temperature poses a negative impact on the chilled food stocks. Therefore, it is imperative to minimise the margin of potential risks that can incur huge losses to the cold-storage industry. On-site evaluation can be relied upon to address these risks, but it is a time-consuming and inefficient process as human intervention can lead to manual errors. Therefore, a methodology is proposed to build an IoT-based cold-storage system to remotely monitor and evaluate cold warehouses using mobile phones or laptops. In addition, this research addresses the difficulty in managing and analysing the large sensory data that is the result of seamless monitoring by harnessing the power of edge computing and cloud computing.

3. METHODS

The research was conducted at NN Frozen Food, Jalan Serayu, Kabupaten Malang. The study took place in July 2024. The materials used is freezer box. The tools used are DS18B20 sensor, PZEM-004T sensor, solar panel, accumulator, LCD, inverter, switch.

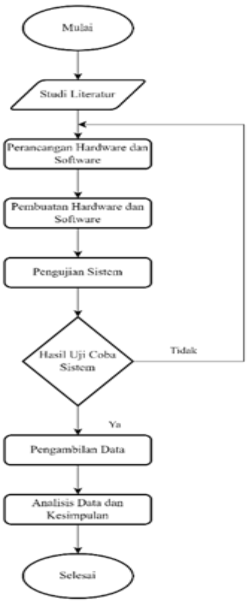

Figure 1. Stages of Research

The stages of research carried out aim to create a structured and detailed research, the stages that will be carried out are shown in the figure above.

1. Literature Study

   At this stage, the search and review of theoretical references that are relevant to the problems found with the aim of obtaining and strengthening the theoretical basis for the problem to be studied. The literature used focuses on scientific journals and theses related to hardware and software parts and objects used as research material.
2. Planning

   It is a tool planning stage related to the design of a wireless-based freezer box temperature and humidity monitoring system and how solar panels work as an alternative to the electrical power used.
3. Creation

   At this stage, the tool is made both in terms of software and hardware so that both can work optimally and in accordance with the plan.
4. Testing

   This is the stage of testing the tool which includes experiments by installing the tool on objects and sending data to the website. In addition, checking whether all components function properly or not.
5. Trial Results

If the results of the test are successful, the data collection stage will be carried out. And if it is not successful, then rechecking is carried out at the planning stage.

6. Data Retrieval
   At this stage, data is collected from sensor readings which can then be displayed on a website that can be accessed via a smartphone/laptop.
7. Data Analysis and Conclusion
   At this stage the results of the system planning will be proven so that conclusions can be drawn from the analysis of the data generated from the testing of the tools that have been carried out.

4. RESULTS AND DISCUSSION

Based on the test results table data, the average value of the freezer box temperature is –24.82°C and the temperature range ranges from –28.81°C to –19.63° C, indicating that the freezer box operates at a low enough temperature to ensure frozen food products are stored in optimal conditions so that product quality is maintained. The voltage values recorded are in the range of 197.10 V - 218.70 V, indicating the voltage is quite stable within the range required for freezer box performance. Any fluctuations in the voltage values could affect the freezer performance and energy efficiency. The power range on the freezer box ranges from 158 W - 186.80 W, indicating the energy required to maintain low temperatures in the freezer box. The larger the power value recorded, the more energy the freezer box is likely to consume during busy store periods when the freezer box will be opened and closed more frequently or when the ambient temperature is high. The range of values for energy, power factor, and frequency data shows a fairly stable range of values. From the data recorded, it is evident that the wireless-based freezer box monitoring system and the implementation of solar panels as an alternative to the power used work well and in accordance with the planning that has been done.

Table 1. Result of Freezer Box Temperature

No.	Date/Time	Temperature (°C)
1.	24/6/2024; 09.00	–23,06
2.	24/6/2024; 09.30	–23,44
3.	24/6/2024; 10.00	–21,13
4.	24/6/2024; 10.30	–22,31
5.	24/6/2024; 11.00	–23,44
6.	24/6/2024; 11.30	–21,56
7.	24/6/2024; 12.00	–22,06
8.	24/6/2024; 12.30	–23,25
9.	24/6/2024; 13.00	–23,63
10.	24/6/2024; 13.30	–19,63
11.	24/6/2024; 14.00	–22,19
12.	24/6/2024; 14.30	–23,06
13.	24/6/2024; 15.00	–21,13
14.	25/6/2024; 09.00	–24,19
15.	25/6/2024; 09.30	–28,00
16.	25/6/2024; 10.00	–28,81
17.	25/6/2024; 10.30	–25,56
18.	25/6/2024; 11.00	–24,94
19.	25/6/2024; 11.30	–27,63
20.	25/6/2024; 12.00	–28,50
21.	25/6/2024; 12.30	–28,94
22.	25/6/2024; 13.00	–24,31

23.	25/6/2024; 13.30	–26,31
24.	25/6/2024; 14.00	–27,88
25.	25/6/2024; 14.30	–28,63
26.	25/6/2024; 15.00	–27,56
27.	26/6/2024; 09.00	–27,19
28.	26/6/2024; 09.30	–28,81
29.	26/6/2024; 10.00	–29,38
30.	26/6/2024; 10.30	–24,13
31.	26/6/2024; 11.00	–26,63
32.	26/6/2024; 11.30	–27,00
33.	26/6/2024; 12.00	–27,31
34.	26/6/2024; 12.30	–27,69
35.	26/6/2024; 13.00	–27,88
36.	26/6/2024; 13.30	–28,25
37.	26/6/2024; 14.00	–28,56
38.	26/6/2024; 14.30	–28,94
39.	26/6/2024; 15.00	–29,13
40.	27/6/2024; 09.00	–28,88
41.	27/6/2024; 09.30	–26,19
42.	27/6/2024; 10.00	–26,31
43.	27/6/2024; 10.30	–27,75
44.	27/6/2024; 11.00	–21,88
45.	27/6/2024; 11.30	–22,50
46.	27/6/2024; 12.00	–21,38
47.	27/6/2024; 12.30	–22,88
48.	27/6/2024; 13.00	–23,06
49.	27/6/2024; 13.30	–23,44
50.	27/6/2024; 14.00	–23,69
51.	27/6/2024; 14.30	–24,25
52.	27/6/2024; 15.00	–19,63
53.	28/6/2024; 09.00	–24,56
54.	28/6/2024; 09.30	–23,50
55.	28/6/2024; 10.00	–24,56
56.	28/6/2024; 10.30	–25,31
57.	28/6/2024; 11.00	–22,19
58.	28/6/2024; 11.30	–21,75
59.	28/6/2024; 12.00	–24,44
60.	28/6/2024; 12.30	–24,81
61.	28/6/2024; 13.00	–25,19
62.	28/6/2024; 13.30	–25,63
63.	28/6/2024; 14.00	–24,19
64.	28/6/2024; 14.30	–18,69
65.	28/6/2024; 15.00	–23,69
66.	29/6/2024; 09.00	–23,88
67.	29/6/2024; 09.30	–25,75
68.	29/6/2024; 10.00	–22,75
69.	29/6/2024; 10.30	–23,56
70.	29/6/2024; 11.00	–24,00

71.	29/6/2024; 11.30	–24,25
72.	29/6/2024; 12.00	–24,44
73.	29/6/2024; 12.30	–24,50
74.	29/6/2024; 13.00	–24,56
75.	29/6/2024; 13.30	–24,69
76.	29/6/2024; 14.00	–24,81
77.	29/6/2024; 14.30	–24,56
78.	29/6/2024; 15.00	–25,06
79.	30/6/2024; 09.00	–25,56
80.	30/6/2024; 09.30	–24,25
81.	30/6/2024; 10.00	–21,00
82.	30/6/2024; 10.30	–25,06
83.	30/6/2024; 11.00	–26,31
84.	30/6/2024; 11.30	–26,94
85.	30/6/2024; 12.00	–25,69
86.	30/6/2024; 12.30	–26,00
87.	30/6/2024; 13.00	–21,81
88.	30/6/2024; 13.30	–21,88
89.	30/6/2024; 14.00	–24,50
90.	30/6/2024; 14.30	–25,38
91.	30/6/2024; 15.00	–25,58
Average value of temperature data		**–24,82°C**

Table 2. Result of System Testing Data

No.	**Data Range**	**Value Data Range**
1.	Suhu	–28,81°C hingga –19,63°C
2.	Tegangan	197,10 V – 218,70 V
3.	Arus	0,02 A – 1,03 A
4.	Daya	158 W – 186,80 W
5.	Energi	37,43 kWh – 55,64 kWh
6.	Frekuensi	50 Hz
7.	Faktor Daya	0,63 – 0,90

The picture below shows the results of the overall component circuit consisting of a monitoring system box, relay, SCC, and inverter. The components are arranged in accordance with their functions and circuit flow. The monitoring system box is at the bottom itself because the DS18B20 temperature sensor will be placed in the freezer box and requires a long cable. Then there are relays and inverters, relays will ensure that the inverter only operates under certain conditions, such as when the power in the battery is full or when there is a power request from the load. The SCC will regulate the charging from the solar panel to the battery so that overcharging does not occur, overcharging can damage the battery and reduce its life.

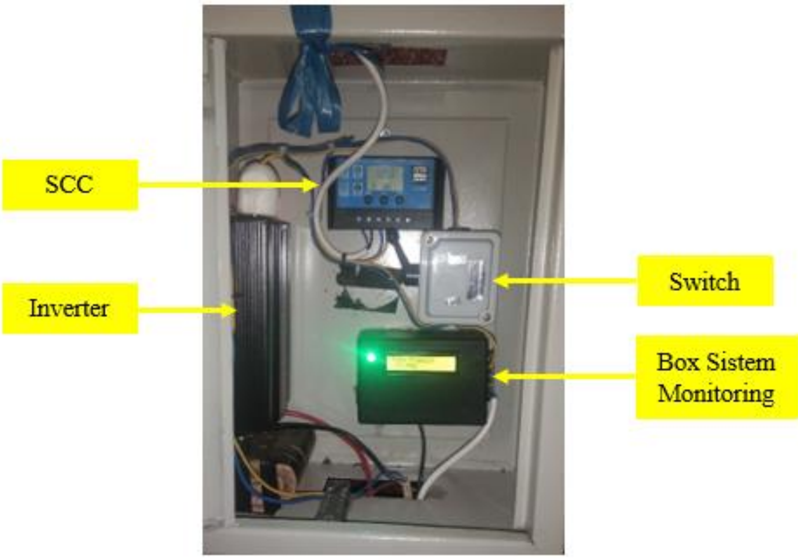

Figure 2. Research Result Model

CONCLUSION

The test results show that this system can maintain the optimum temperature of the freezer box for the storage of frozen food products with high efficiency and good reliability. Solar panel technology successfully provides alternative electrical power by converting sunlight into energy, which is stored in batteries and converted into AC current to operate the freezer box. Overall testing shows the system functions as designed with a temperature sensor and hygrometer accuracy of 99.63%, and the average temperature of the freezer box reaches -24.82°C.

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