Temperature Monitoring System on Distribution Transformer with Web Thermal Camera

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Abstract : Temperature monitoring using a thermal camera is one type of light inspection that is used as an indicator of the health of a transformer. The system can detect the temperature of a transformer without having to stick directly to the surface of the transformer. The results of temperature measurements from the sensor are displayed in the form of images that canbe displayed on a web. In this final project, a transformer temperature monitoring system is made that continues to workin real time to measure the temperature of the transformer. This is because changes in the temperature of the transformercan occur at any time. With this system, workers are expected to always monitor the condition of the transformer without having to make onsite visits. In this final project, ESP32 is used as a microcontroller and MLX90641 thermal camera. The use of a thermal camera in this system is caused by several advantages, namely the thermal camera can take the temperature of all parts of the transformer captured on the camera. In addition, the thermal camera has a range of up toseven meters. In this system, the temperature capture is set at the hottest point of all visible camera pixels. This system is also equipped with a notification system that will work when the temperature of the hamster transformer exceeds 60℃. The normal temperature threshold of the distribution transformer is 30℃-80℃. Or the maximum increase in one day of40℃ from the initial temperature. The temperature of the transformer's hottest point will trigger a notification display ina web. So that after receiving a notification the officer can immediately know the temperature of the transformer and immediately take action. From the results of experiments that have been carried out, it is known that the results of measuring the temperature value of the thermometer and sensor have an accuracy rate of 98.8%. In addition, the systemalso works well, this is indicated by the color difference that occurs when the transformer temperature is in normal and hot conditions. So that from the image displayed, the officer can already know that the measured transformer is in normalor overheated conditions.

Keywords: *transformers, MLX90641, web*

1. Introduction

As one of the important electrical components in an electric current distribution, the maintenance of a transformer certainly needs to be done regularly. Because it will also affect the performance of the transformer. In addition to bushings, checking the temperature of the transformer is one of the maintenance that must be done. The maximum temperature limit for transformer performance is 80°C and the maximum temperature increase is 60°C from the initial temperature. However, during this time checking the temperature on the transformer is still done manually by workers. Which of course can't be on standby for 24 hours, while load spikes that cause the
temperature in the transformer cable to increase can occur at any time.

When the transformer is in operation, the part of the transformer that carries current will generate heat. An abnormal temperature in the transformer can be interpreted as an abnormality in that part or location. One of the methods for monitoring the transformer temperature as a whole to see whether there is an abnormality in the transformer is using a thermovision/thermal imaging camera. The use of a thermal camera is very good because it can detect the heat source from the entire surface of the transformer. Meanwhile, if you use an ordinary wireless temperature sensor, the measured data only focuses on one point so that the heat in other parts will not be seen.

In previous research, there was already a temperature monitoring tool that was used as a measuring tool to determine the temperature value of the transformer cable in each phase. Measurements were made using DHT22 as a temperature sensor. If the temperature of the transformer cable shows a value of less than 40°C, then the transformer is in normal condition. In excess conditions, Arduino will send a message containing temperature information to the officer (Saniya, 2018). But on the other hand, the use of the DHT 22 sensor has a weakness, namely it only displays measured data in general. Including the temperature of the room. It will be a problem to distinguish between the room temperature and the temperature of the transformer.

Based on the problems that have been described, in this final project, a tool is made that is used to monitor the temperature of a transformer remotely using a thermal camera. The measured data will be in the form of images that are displayed in real time from the sensor via the ESP32. Furthermore, the measured data that has entered the database is displayed through the User Interface on a web. With this tool, workers will be able to monitor the temperature of the transformer from anywhere and anytime. This of course can speed up the response of workers when a temperature anomaly occurs in a distribution transformer.

Literature review

So far, checking the temperature of the transformer cable is done manually and not continuously, so a tool is needed that can monitor continuously and realtime. The measured data will be in the form of images that are displayed in real time from the sensor via the ESP32. Furthermore, the measured data that has entered the database is displayed through the User Interface on a web. With this tool, workers will be able to monitor the temperature of the transformer from anywhere and anytime. This of course can speed up the response of
workers when a temperature anomaly occurs in a distribution transformer. As a literature review, the following are some previous studies that contain several final assignments and journals related to this final project. The first is the final project entitled "Prototype Monitoring Current, And Temperature In Internet Of Things (IoT)-Based Distribution Transformer". This thesis research aims to design and create a prototype of a current and temperature parameter monitoring system on an IoT-based transformer to increase efficiency, lifetime and determine the condition of the transformer in real time. The results of this study indicate that the prototype tool when compared to ampere pliers can respond to the readable 3-phase current value with an average measurement error or error accuracy per phase current R = 1.0%, S = 1.8%, T = 1 , 7%, and the average

measurement error or temperature error accuracy per phase is R= 3.1%, S= 5.8%, T= 8.0%. (Madjid & Suprianto, 2019)

Next is the Final Project entitled "Arduino- Based Transformer Cable Temperature Monitoring Tool With Sms". This temperature monitoring tool is used as a measuring tool to determine the temperature value of the transformer cable in each phase. Measurements were made using DHT22 as a temperature sensor. If the temperature of the transformer cable shows a value of less than 40°C, then the transformer is in normal condition. In excess, Arduino will send a message containing temperature information to the officer. So that officers can find out if the temperature is too high and take action immediately. The results of temperature monitoring will be displayed on a 16x2 LCD and then displayed to the smartphone in the form of a text message. (Saniya, 2018)

tests of how to operate. the comparison of the transformer temperature measurement with a thermometer at a load of 4 21W lamps and 2 8W lamps reads a current of 4.3 A and an average error difference of 1.32%. So it is hoped that this tool can provide knowledge to the wider community about the transformer temperature monitoring system in maintaining the electric power transmission system well and easy to understand. (Winardi, 2017)

2. System Planning and Design

Requirements Analysis

At this stage, observations are made about where the system will be placed, the security of the system, and what needs are needed to build the system.

Planning

At the planning stage, a temperature monitoring system will be created on a web-based distribution transformer that provides information about the temperature conditions of the distribution transformer in real time. Making this system will be completed with the waterfall method. To build a temperature monitoring system on this web-based distribution transformer, a thermal camera sensor will be used on the substation area to detect temperature changes in a distribution transformer. For the microcontroller used is ESP32. This system will use a database to store data from sensors. The database used is mySQL. The data that has been obtained from the sensor will be uploaded to the database via the access point. The access point in this system uses Wifi Portable mini Andromax M3Y.

2.1 Hardware Design

At this design stage, a discussion of the work plan is carried out by setting the right time estimate, scheduling, and overall tool design, coding Arduino IDE and Visual Studio Code and mysql, to displaying data results on smartphones, and estimating the cost budget needed in making the system. this. At this stage, a wiring diagram is also made which shows the sequence of the system creation process. The following is a display of a web-based transformer temperature monitoring system block diagram

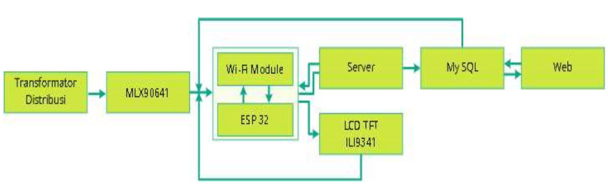


Figure 1 Temperature Monitoring System Block Diagram Transformer Using Web Based Thermal Camera

In this final project, the design of the tool uses an ESP32 microcontroller as the main controller of all systems. The software consists of a program created in the Arduino IDE and then uploaded to the ESP 32 microcontroller. The ESP32 then processes the captured image from the MLX90641 sensor with the interpolation method. After the image quality improvement is successfully carried out, then ESP32 displays the image on the TFT LCD and simultaneously requests server access in this case a VPS (Virtual Private Server) to send data. After the request is received, ESP32 sends the measurement data to the My SQL database. Data from the database is then retrieved and displayed in the form of images and charts on a web.

2.2 Software Design

The software design in this final project is intended to design programs on ESP32. The software design in this final project uses Arduino IDE to create a program that will be used in making the system. ESP32 itself functions as a processor and sender of data to the database.

The purpose of this study is to find out that every change in transformer temperature can be monitored automatically with the HMI display through the VTScada software which is connected to the Arduino Mega 2560 via an ethernet shield and router. This simulator tool has been carried out several measurements and attention to convenience both in terms of features, buttons, colors or fonts used. So that this can make the web that is made easy to use by the user.

To create a prototype interface design in this project, the figma application is used. The following is a design of several pages that are used to display data from the MLX90641 temperature sensor.

Flowchart Temperature Monitoring System Temperature Monitoring Distribution Transformer is showed in the figure 2.

The flowchart shows that when the device is turned on, an initialization process occurs. The initialization process consists of checking sensors, wiring and connections. After the initialization process runs, the MLX90641 sensor starts reading temperature data from the object being measured. The measured data is then displayed into the TFT LCD. Along with the measured data, the ESP32 contacts the server to request data transmission access. Access requests to the server are only made once. Once access is accepted ESP32 starts sending data to the server. The data in the form of images is displayed directly on the web while the temperature values are stored in the mySQL database first.

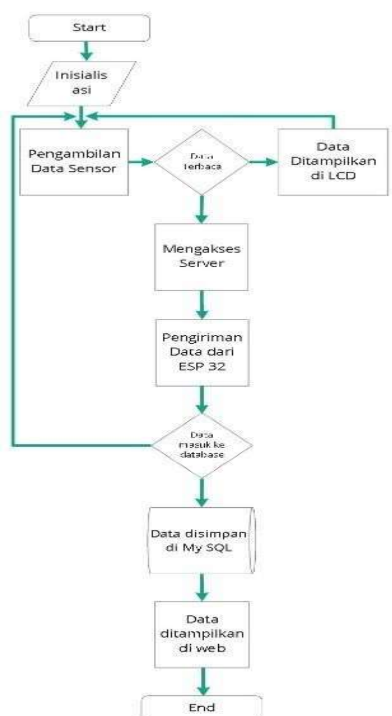


Figure 2 Flowchart Temperature Monitoring System Temperature Monitoring Distribution Transformer

At this stage the author realizes the design in the previous stage, namely the design by making non-contact temperature monitoring on the transformer. This stage begins with preparing the materials to be used, including the MLX90651 IR thermal camera sensor ESP32, TFT LCD, buzzer then start designing the electronicdevice

At this stage it is explained about the implementation of the system design that has been made previously. In making this system used several devices such as ESP32, TFT LCD, MLX90641, and buzzer. With the addition of a buzzer, it is hoped that when the transformer has a temperature above normal, a notification will appear either in the form of sound or words that can be read from the LCD and the web.

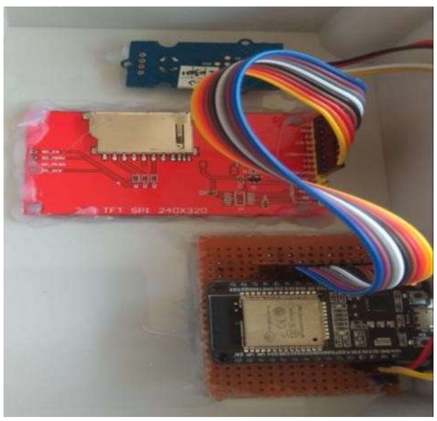


Figure 3 Implementation of Tool Installation on the box

2.3 Implementation on Arduino

The first step before uploading a program on Arduino is to add a library to the Arduino IDE by selecting Sketch => Inculde Library => Manage Libraries

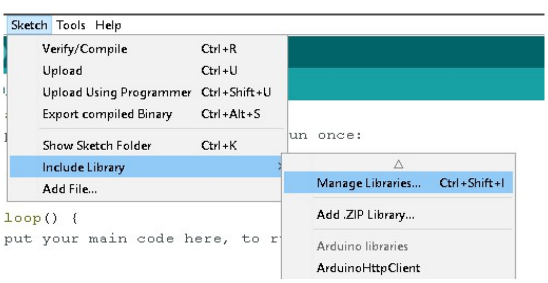


Figure 4 Adding a Library to the Arduino IDE

The next steps are

1. Arduino IDE updates the list of installed libraries.
2. Install the ArduinoWebsockets library.
3. Install the TFT_Espi library
4. Adding a Library for theMLX90641 Sensor
5. Entering the Sensor LibraryMLX90641
6. Checking Ports on Arduino IDE
7. Uploading Script
8. Setting Wifi and setting MinTemp and MaxTemp
9. Setting standard deviation of RGB

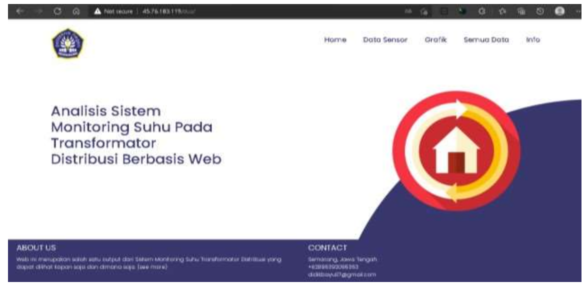


Figure 5 Initial Display using Web based thermal camera

In the sensor results section, a live streamingimage and temperature sensor value will be displayed in real time.In the graph section, the temperature sensor value data will be displayed.

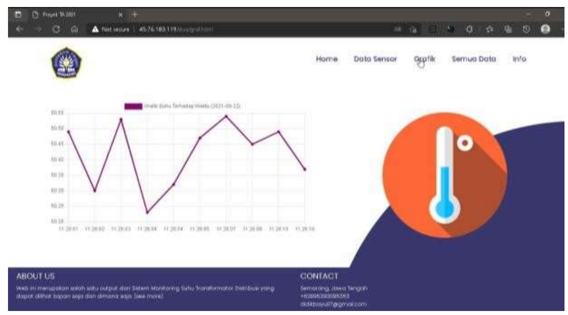
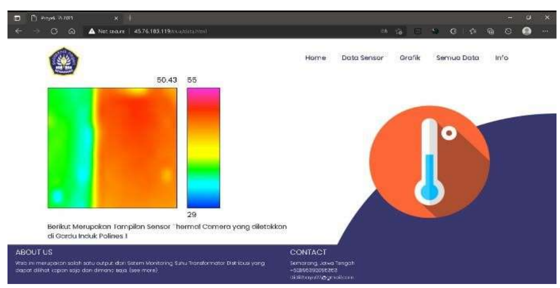


Figure 6 Graphic display of Thermal Camera Temperature sensor MLX90641

Figure 7 Display of Color Image of the Thermal



Camera MLX90641

3. Test Results and Analysis

In this chapter the author will describe andexplain some of the results of the testing and research of this Final Project. The author will also analyze the system that has been created. The purpose of this chapter is to determine the level of success of the system design that has been proposed and carried out.

This test was carried out at different times, namely morning, afternoon, and evening. This is because to find out the temperature of the transformer at different times is it stable or there are changes and colors produced by the sensor based on the temperature of the transformer. The normal temperature of the transformer is between 36.1°C to 38.9°C (drh. Febiola Nur Sabrina). Then also see a comparison of the color spectrum on the MLX90641 sensor. The advantages of this sensor is it shown the spread of temperature in the cable of transformator.

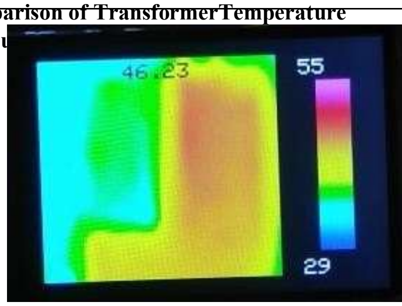
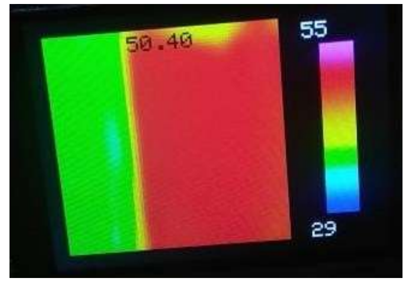
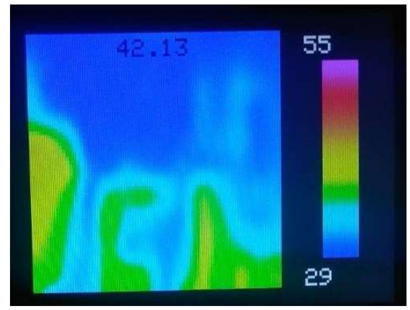
In the data section most recent values from the data read by the temperature sensor will be displayed and stored in the database.

The color division on the MLX90641 sensor output display is described by the color spectrum on the right of the image as can be seen in Figure 19. The color spectrum is a color sequence that shows the range between the minimum to maximum temperature of the measured object. In this final project, the temperature range is set according to the objectused, namely the transformer. The temperature range is between 32°C to 39°C. The order of colors on this temperature spectrum starts fromthe lowest temperature to the highest temperature. The order of temperature is dark blue => light blue => green => yellow => orange => red => purple. The color sequence starts from dark blue which indicates the lowest or minimum temperature. Then, purple when the temperature reaches the highest or maximum point.

Figure 8 Display image of Temperature Sensor Results on TFT LCD

Table 1 is the result of testing temperature data and pictures of the tools that have been made. The tests were carried out at different times, namely morning, afternoon , and evening.

Table 1.Comparison of TransformerTemperature Test Data Results

Morning	
Afternoon	
Evening	

In the figure in table 1, the results of the distribution transformer temperature measurements are shown in the morning,afternoon, and evening. Based on the picture, itcan be seen that in the morning the dominant temperature shows a light blue color, this indicates the condition of the wall temperature around the distribution transformer in a condition below the measured transformer temperature. The significant difference between the wall temperature and the distribution transformer temperature causes thethermal image to be printed clearly. The measured transformer temperature can be identified by the presence of a yellow hottest temperature point which indicates a temperature of 42.13°C. This temperature is a working temperature that is two degrees higher than the normal working temperature of a transformer which ranges from 30°C-40°C. However, this condition is still within normal limits. Furthermore, the green color in the picture is the other side of the transformer which has a temperature that tends to be cooler.In the transformer section there are also parts that seem hollow, this does not mean that the transformer section is actually hollow.

However, there are several sides of the transformer that have a temperature similar to the wall. So this causes the part of the transformer that tends to be cooler to be read by the sensor as a wall. In the last picture, picture number five, the transformer parts that seem hollow have disappeared. This is because all parts of the transformer begin to have an even temperature. So it looks like a picture of atransformer that is intact and not perforated like the previous 4 pictures. In the picture, the outer part of the transformer also shows a light blue layer. This shows that the temperature of the transformer was emitted before finally mergingwith the temperature of the environment.

During the day the temperature of the transformer has increased quite high, reaching 50.76°C. The temperature on the TFT LCD is depicted in solid red in all parts of the transformer. The outer part of the transformer is shown in yellow. The color is the heat emitted by the transformer. In addition to the reduced heat because it is the heat emitted by the transformer. The temperature of the emission also becomes cooler because the Semarang State Polytechnic Substation room is equipped with six fans and a blower. This is used to maintain the temperature of the transformer so that it continues to work within normal limits and does not heat up quickly. This is because the transformer works continuously for twenty- four hours a day. With the transformer temperature reaching 50, This shows that the transformer works with a heavier load. This load can also be seen by the amount of current that is read on the pliers which reaches 292.8 Ampere. In addition to the dominant red and yellow colors in the image, the green part is alsovisible. This part is the wall temperature that is read by the MLX90641 sensor. This is differentfrom the wall temperature data in the morning which is blue and shows a cooler value. Duringthe day the temperature of the walls reads also becomes hotter, this is also due to the increase in ambient temperature during the day. So that the wall also experiences an increase in temperature compared to the morning. 8 Ampere. In addition to the dominant red and yellow colors in the image, the green part is also visible. This part is the wall temperature that is read by the MLX90641 sensor. This is differentfrom the wall temperature data in the morning which is blue and shows a cooler value. During the day the temperature of the walls reads also becomes hotter, this is also due to the increase in ambient temperature during the day. So that the wall also experiences an increase in temperature compared to the morning. 8 Ampere. In addition to the dominant red and yellow colors in the image, the green part is alsovisible. This part is the wall temperature that is read by the MLX90641 sensor. This is differentfrom the wall temperature data in the morning which is blue and shows a cooler value. Duringthe day the temperature of the walls reads also becomes hotter, this is also due to the increase in ambient temperature during the day. So that the wall also experiences an increase in temperature compared to the morning. This is also due to the increase in ambient temperature during the day. So that the wall also experiencesan increase in temperature compared to the morning. This is also due to the increase in ambient temperature during the day. So that thewall also experiences an increase in temperature compared to the morning.

This condition illustrates that not every part of the transformer has the same temperature. In the picture, the dominant temperature of the transformer is detected in yellow, which means it indicates that the temperature of the transformer is not ashot as during the day. There was also a change in the color of the walls from green in the afternoon to the afternoon the temperature of the walls decreased and was detected with a light blue color. So based on this it can be concluded that the transformer temperature is cooler in the afternoon than during the day.will be displayed in different colors according to the temperature range. And the hotter the temperature captured, the display on the TFT LCD will show the highest color spectrum compared to other objects with lower temperatures.

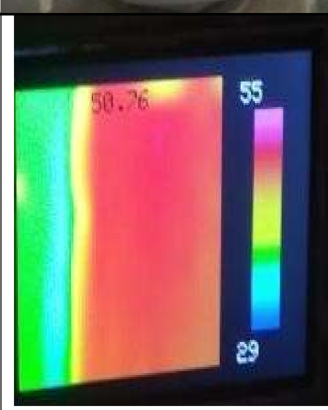
As shown in table 1 in the cage containing an object, the hottest point willbe detected in yellow. The yellow color has an order of magnitude higher than the blue in the color spectrum of a thermal camera. And what is detected with the yellow color is thetransformer with the green circle being the outer body temperature of the transformer. Forthe blue color is from the temperature of the sand. The sand reflects infrared signals so that it has a temperature that can be read or captured by a thermal camera. Meanwhile, for the thermal camera which is not provided with a transformer in the enclosure, only thetemperature of the dark blue sand can be detected.

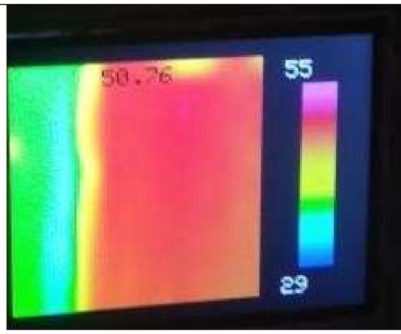
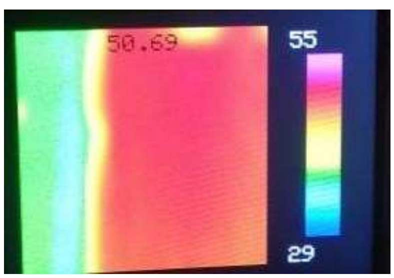
Comparison of Calculations betweenMLX90641 Sensor and Thermal Relay

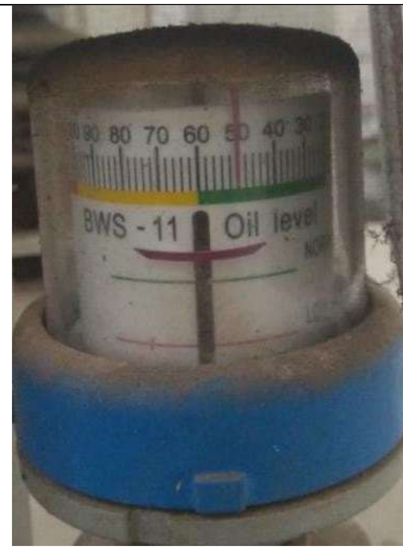
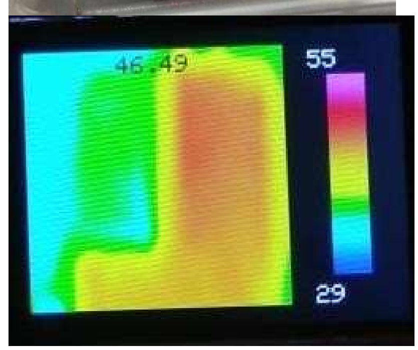
Table 2 shows the results of the display on the calibration test and the comparison of the MLX90641 sensor with a digital thermometer measuring instrument at several different times. Error rates are obtained from the formula:

((Difference between thermometer and sensor output) / Thermometer) × 100

Table 2 Difference error of Temperature Data Results between Temperature Sensors and DigitalThermometers

%Error	Picture
0.76	
	

	 50.76 55 29
0.69	 80 70 60 50 40 30 BWS - 11 Oil level  50.69 55 29

0.88	 80 70 60 50 40 30 BWS - 11 Oil level  50.88 55 29
0.49	 40 60 80 100 120 °C  46.49 55 29

0.22	 

Table 2 shows that thermal camera MLX90641 shows the spread of heat and accurate data temperature. To ensure that the result of thermal camera measurement is accurate, in this research we compare with the digital rele thermometer. Figure 9 shows the campuration between 2 device

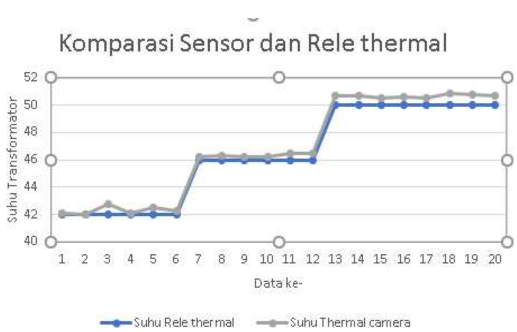


Figure 9 The Comparation Measurement Result between thermal Camera And Digital Rele Thermometer

The comparison test in figure 9 shows that the measurement results using the MLX90641 sensor and digital thermometer do not have much difference. This shows that the tool that has been made has a good and precise level of accuracy. Each temperature generated by each image in each measurement between thetemperature sensor and thermometer shows an error that occurs on average below 1°C.

4. Conclusion

1. In the process of making this final project, the author tries to provide suggestions so that the use of the tool can work more optimally and so that further improvements and developments can be made as needed.
2. The thermal camera measure the temperature and shows the image of the spread of heat on transformer cable.
3. The thermal camera measurement result accurately, the % error less than 1 % with the digital thermomet
4. System is able to shows the measurement data on Web and recorded in the data base.

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