MODELING FOR TANSFORMER CONDITION MONITORING USING IoT: TEMPERATURE AND OIL LEVEL PARAMETERS

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Abstract

Distribution transformer are important components in electrical system, functioning to reduce voltage from the transmission network to end users. Damage to transformeris often caused by unmonitored operations such as high temperature, low oil lvels, and trapped gas, which can disrupt the stability of the power system. Therefore, a monitoring device is needed to maintain the transformer so that it can provide maximum output, reduce the risk of failure, and extend the operational life of the transformer. This study uses a DS18B20 sensor and a VL53L0X sensor, with the DS18B20 sensor reading temperature parameters and the VL53L0X sensor measuring oil level parameters. The DS18B20 and Vl53L0X sensors are controlled by ESP32 and serve as centralized connectivity connected to Blynk. Furthermor, the Internet of Things (IoT) platform will display temperature and oil level parameters from both sensors in real time. This research produced a fairly good system. There was no difference between the readings on the LCD and the Blynk application, and indicators such as LEDs and Buzzers worked well. When the temperature or oil level exceeded the threshold, which was 4 cm for oil level and 50°C for temperature, not only did the indicators turn on, but the relay also turned on. This, it is hoped that the development of this tool can assist in monitoring transformer to extend their lifespan, thereby maximizing transformer productivity.

Keywords: Blynk; Condition Monitoring; Distribution Transformer; ESP32; IoT; Oil Level; Relay; Temperature

Introduction

Transformers are key components in distribution systems that function to increase and decrease AC voltage. Transformers play an important role in distributing electrical power to consumers (Fretes, 2022) and in this process, various disturbances often occur that can hinder the distribution of electrical power. One of the common disturbances includes high temperatures, low oil levels, and trapped gas, which can disrupt system stability. Real-time monitoring of transformer conditions is a major concern in the electricity industry. With the development of the Internet of Things (IoT) system, monitoring can be done automatically, efficiently, and in an integrated manner. Transformers themselves work based on the principle of electromagnetic induction discovered by Michael Faraday, which states that changes in the magnetic field can generate electromotive force (EMF) in a coil of wire. Transformers have two main components, namely the Primary Winding and the Secondary Winding. The primary winding receives the input voltage and creates a changing magnetic field, while the secondary winding receives induction from the magnetic field generated by the primary winding, producing the output voltage. Commonly used types of transformers include step-up transformers, which increase voltage from a low level to a higher level, typically used in power generation and transmission, then there are step-down transformers that lower voltage from a high level to a lower level, typically used in distribution substations to provide the appropriate voltage for consumers, autotransformers that have primary and secondary windings that are electrically connected for higher efficiency, and isolation transformers that are used to electrically separate circuits while still transferring power. Several previous studies have developed similar systems, one of which is the study (Ramadhan Pratama and Purnawan, 2020) entitled "Design of a Temperature and Oil Level Control System on a Power Transformer Prototype". The results of the testing showed that the system could operate automatically and respond to changes in conditions. In this study, the researchers used a DS18B20 temperature sensor. The second study was conducted by (Baharudin et al., 2022) entitled "Design of an Online Transformer Temperature Monitoring System Using an IoT-Based WhatsApp Application: A Case Study at the PLN 150KV Mekarsari Substation." The results of the test showed that the system could provide accurate and timely information. In this study, the sensor used was a PT100 sensor. The third study by (Amol A. Sonune, 2020) entitled "Condition Monitoring of Distribution Transformers using IoT." Using this system, monitoring becomes more accurate and efficient compared to manual methods. This study used PT100 and JSN-SR04T sensors. Based on previous studies, the researcher offers a new approach through the use of DS18B20 sensors for temperature and VL53L0X sensors based on Time-of-Flight (ToF) for high-accuracy oil level measurement. This system also uses ESP32 as a control center with connectivity to the Blynk application, as well as LED indicators, buzzers, and relays to provide visual and audio warnings. This innovation is expected to improve the efficiency and safety of distribution transformers in the long term.

Material and Methods

This research was conducted over three months, from October to December 2024 in Gonilan, Sukoharjo. The initial step was a literature study, which aimed to master the material on reading and sending sensor data with ESP32 and connecting it to LEDs, buzzers, and relays. In addition, development was also carried out by connecting the data to IoT through the Blynk application. This system consists of several main components, namely:

a. **ESP32** as a microcontroller.

Figure 1. ESP32

ESP32 is a microcontroller developed by Espressif System, functioning to manage and process all ports and ICs. This microcontroller is also equipped with the ability to connect to the internet via a wireless network, without requiring an additional board, as it is equipped with a Wi-Fi module in the chip, making it ideal for developing Internet of Things-based applications (Baharudin et al., 2022).

b. **Sensor DS18B20** for measuring oil temperature.

Figure 2. DS18B20 sensor

The DS18B20 temperature sensor is an electronic component that converts temperature into an electrical quantity in the form of voltage. This sensor has a digital output, which can read temperatures with an accuracy of 9 to 12 bits, in the range of -55°C to 125°C (Suryana, 2021).

c. **Sensor VL53L0X** for measuring oil level.

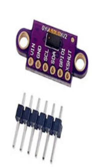

Figure 3. VL35L0X sensor

The VL53L0X is a laser sensor that utilizes Time-of-Flight technology to measure distance. This sensor is equipped with a VCSEL (Vertical Cavity Surface Emitting Laser) at a wavelength of 940 nm. The offset range is marked by the average offset, which is the actual distance measurement, and for optimal offset calibration, a distance of 10 cm is recommended (Dallas, 2024).

d. **LCD 16x2** as the display for temperature and oil level values.

Figure 4. 16x2 LCD

This LCD functions as a screen to display data generated by the microcontroller. Operating at 5V, this device uses the SDA and SCL pins to communicate with the main controller. The LCD has a display capacity of 16 lines and 2 columns of characters and supports integrated I2C addressing.

e. **LED, Buzzer, dan Relay** sebagai indikator kondisi.

Figure 5. LED

Figure 6. Buzzer

Figure 7. Relay

LEDs are electronic components made of semiconductor materials and are often referred to as LED diodes. LEDs are capable of emitting monochromatic light when an electric current flows through them. So in this case, LEDs can convert the electrical energy they receive into light (Sejahtera, 2022).

A buzzer is an electronic component that functions to convert electrical energy into vibrations or sound. Buzzers are often used as indicators to signal that a process has been completed, or to warn of errors or problems in the system. With their ability to produce sound, buzzers are effective tools for providing signals or notifications in various electronic applications (Nadziroh, 2021)

A relay is an electronic switch that can be controlled via an electrical signal. When given an electrical signal, the relay contacts will open and close, allowing electrical current to flow or be interrupted as needed. This makes it easy and efficient to activate and deactivate external devices (Prastyo, 2024)

f. **Aplikasi *Blynk*** for real-time remote monitoring using a Wi-Fi connection.

Figure 8. Blynk Application

Blynk is an Internet of Things (IoT) platform that can be used to connect IoT hardware with an IoT platform. Using this platform, you can control and monitor hardware remotely. Additionally, this platform can store data from sensors and display the measurement results (Teknik Elektro ITI, 2023).

Result and Discussion

Test results show that the system can read temperature and oil level parameters with good accuracy and send data to the Blynk platform in real-time.

1. **DS18B20 Senosr Testing :**
   The DS18B20 sensor is used to detect temperature. Test results show that the sensor is capable of reading temperatures ranging from 27°C to 50°C with an accuracy of ±0.5°C.
   The Temperature Criteria :
   Test Temperature Criteria: The DS18B20 sensor was tested using hot water as the medium for measuring temperature, following the standards from the reference (Ramadhan Pratama and Purnawan, 2020).
   Safe <40°C
   Warning 40°C ≤ X < 50°C
   Critical ≥50°C

The test results can be seen in Figures 9 and 10 and Table 1:

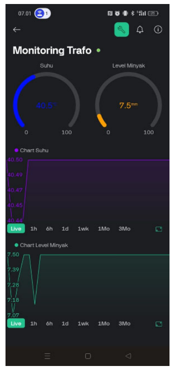

Figure 9. Blynk Display

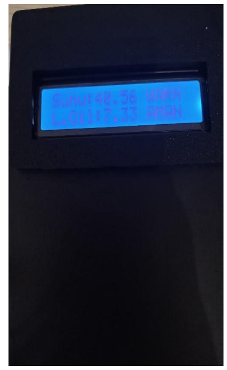

Figure 10. 16x2 LCD Display

Table 1. DS18B20 Sensor Testing with Temperature Parameters

No.	Initial Condition	Measurement Results	Status	Description
1	Normal	27,69 °C	Safe	Oil temperature within safe limits. Green LED on, buzzer off, relay off
2	High	48,75 °C	*Warning*	Oil temperature is approaching the critical limit. Yellow LED on, buzzer off, relay off
3	High	50,06 °C	Critical	Oil temperature exceeds critical limit. Red LED on, buzzer on, relay on
4	Low	40,56 °C	*Warning*	Oil temperature is approaching the critical limit. Yellow LED on, buzzer off, relay off
5	Normal	39,31 °C	Safe	Oil temperature within safe limits. Green LED on, buzzer off, relay off

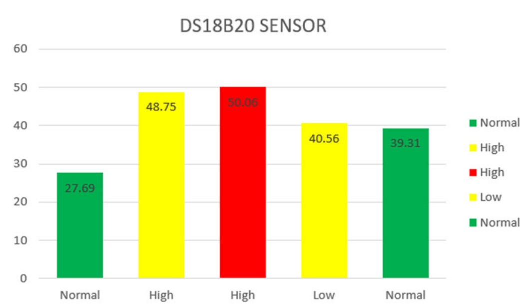

Figure 11. DS18B20 Sensor Reading Results

Based on the test results, the sensor is capable of reading temperatures within the range of 27°C to 50°C with good accuracy relative to the reference value. Normal conditions were recorded at two measurement points, namely 27.69°C and 39.31°C, indicating that the temperature is still within the operational tolerance threshold. High conditions were recorded at 48.78°C and 50.06°C, indicating that the temperature has approached or even exceeded the safe limit and entered the warning and critical zones. Based on this data, the DS18B20 sensor works reliably in detecting changes in transformer oil temperature. Under normal conditions (27.69°C), the system provides a safe indication with a green LED lit. When the temperature rises to near the operating limit (48.75°C), the system status changes to warning with a yellow LED lit as a warning sign. When the temperature exceeds the operating limit (50.06°C), the system automatically activates a red

LED, buzzer, and relay as an early warning to prevent further damage. When the transformer is cooled, the temperature slowly decreases to 40.56°C, indicating a critical but stable condition. After the cooling process continues, the temperature returns to 39.31°C and the system automatically returns to a safe condition with the green LED lit. This proves the system's ability to respond quickly and accurately to temperature changes and detect the transformer's thermal dynamics in *real-time.*

2. **VL53L0X Sensor Testing**

   The VL53L0X sensor is used to detect oil levels in the transformer. This sensor can measure heights within a range of 3-7 cm.

   Oil level criteria:

   VL53L0X sensor testing was conducted using black-colored water to enhance contrast and facilitate the sensor's detection of liquid levels. The sensor was placed on top of a container filled with water, and oil level measurements were taken by varying the water height according to the standard reference from (Dallas, 2024)

   Safe > 6 cm

   Warning $6 \text{ cm} \le X > 4 \text{ cm}$

   Critical $\le 4 \text{ cm}$

   Test results can be seen in Figures 12 and 13 and Table 2:

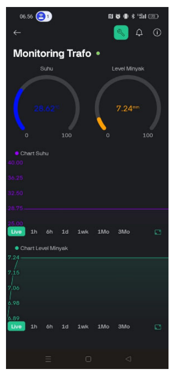

Figure 12. Blynk Display

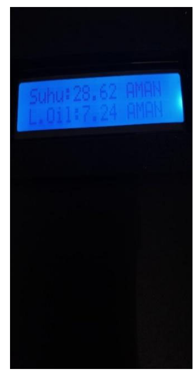

Figure 13. 16x2 LCD Display

Tabel 2. VL53L0X Sensor Testing with Oil Level Parameters

No.	Initial Condition	Measurement Results	Status	Description
1	Normal	7,24 cm	Safe	Oil level within safe limits. Green LED on, buzzer off, relay off
2	Decreasing	5,50 cm	*Warning*	Oil level is approaching the critical limit. Yellow LED on, buzzer off, relay off
3	Decreasing	3,50 cm	Critical	Oil level exceeds critical limit. Red LED on, buzzer on, relay on
4	Increasing	5,24 cm	Warning	Oil level is approaching the critical limit. Yellow LED on, buzzer off, relay off
5	Normal	7,24 cm	Safe	Oil level within safe limits. Green LED on, buzzer off, relay off

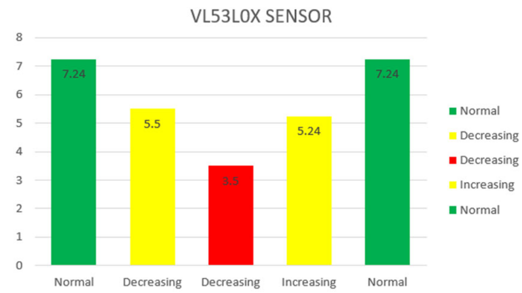

Figure 14. VL53L0X Sensor Readings

Based on the test results shown in Table 2, the VL53L0X sensor is capable of accurately detecting oil levels and providing responses according to the monitored conditions. This sensor works based on the Time of Flight (ToF) principle, which measures the travel time of a light signal from the transmitter until it is reflected back by the liquid surface. The readings produced indicate a high sensitivity to changes in the oil surface level.

Under normal conditions with an oil height of 7.24 cm, the green LED indicator lights up to indicate that the system is in a safe condition. When the oil level decreases to near the critical limit (5.50 cm), the system issues a warning in the form of a yellow LED to indicate a warning condition. If the oil level continues to decrease beyond the critical limit (3.50 cm), the system automatically activates a red LED, relay, and buzzer as an emergency warning sign of potential disruption or damage to the transformer due to a lack of cooling media.

When oil is then added until it reaches 5.24 cm, the system status changes back to warning, indicating that the oil level is approaching the safe limit but is not yet completely stable. After adding oil until it reaches 6.37 cm, the system detects that conditions are back to normal, indicated by the green LED lighting up again. Normal conditions were recorded at two measurement points, namely 7.24 cm and 6.37 cm, indicating that the oil level was at the ideal height and the system was in a safe condition. When the oil level drops to a critical limit, the system automatically activates a red LED, buzzer, and relay as a warning signal. This shows that the system works reliably in monitoring changes in oil level and is capable of providing an automatic response according to the detected conditions .

3. **IoT Integration with the Blynk App**

The ESP32 will send sensor data to the Blynk application, which will then display it in the form of numerical values and graphs. If the connection is lost, the system will automatically reconnect to ensure the next data transmission. The test results can be seen in Figure 15 and Table 3:

Table 3. Blynk Testing on the IoT System with Real-Time Data

No.	Initial Condition	Measurement Results	Description
1	Connected	Data received	Data received on the IoT platform (Blynk)
2	Not connected	Data not received	The IoT system is not receiving data
3	Reconnected	Data received	Data received on the IoT platform (Blynk)

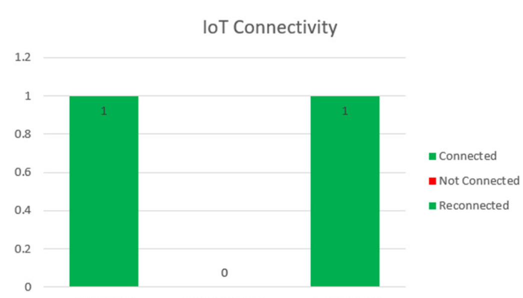

Figure 15. IoT Connectivity Results

When the system is connected, data is successfully sent and received by the application (indicated by a value of 1). When disconnected, the system does not send data due to network interference, indicated by a value of 0. Once the network is restored, the system is able to reconnect and resume sending data normally. The results of this testing indicate that the system has stable connectivity and can display real-time condition changes both on the LCD and in the Blynk application.

Conclusion

This research successfully developed an Internet of Things (IoT)-based transformer condition monitoring system using DS18B20 and VL53L0X sensors controlled by ESP32. The system is capable of providing accurate temperature and oil level readings and displaying data in real-time through the Blynk application. Test results show that the system has a high level of reliability in measuring temperature and oil level parameters, with a very small measurement difference compared to the reference value.

The LED indicator, buzzer, and relay function effectively in providing early warnings of critical conditions, such as temperatures exceeding 50°C or oil levels falling below the 4 cm threshold. This automatic response mechanism proves that the system is capable of quickly detecting and responding to changes in conditions, thereby preventing damage to the transformer due to overheating or lack of insulating lubricant. Additionally, the IoT connectivity system demonstrates good stability with automatic reconnect capability when the Wi-Fi network is interrupted, ensuring that monitoring data is still transmitted without losing important information.

From a technical standpoint, the use of ESP32 provides advantages because this microcontroller has a dual processor and stable wireless connectivity, making it suitable for IoT-based monitoring applications. The DS18B20 and VL53L0X sensors have also proven to be efficient and easy to integrate, with a high level of sensitivity to environmental changes. The combination of these two sensors allows the system to not only read static conditions, but also continuously detect trends in temperature and oil level changes, which can be used as a basis for transformer health analysis.

Thus, this system not only functions as a monitoring tool, but also has the potential to be developed into a diagnostic and predictive system capable of comprehensively monitoring transformer performance. The implementation of an IoT-based monitoring system such as this can assist electricity distribution companies in performing preventive maintenance and reducing the risk of transformer failure in the field.

The designed system can be a practical and efficient solution to improve the reliability of the power distribution network while extending the operational life of transformers. Further research can focus on adding other monitoring parameters such as current, voltage, and gas pressure, as well as applying machine learning to historical data analysis so that the system can automatically predict potential damage in the future.

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