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Prototype of Voltage, Current, Temperature, and Oil Level Monitoring System in Transformers

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ABSTRACT

A distribution transformer is the most crucial component of the electric power distribution system. The output values of parameters such as voltage, current, temperature, and oil level vary, necessitating monitoring. This final project aims to design and build, determine the functional testing of the device, and assess the performance accuracy of its components. The system design results show that the components used in the prototype system are the INA219, AHT10, and HC-SR04 sensors. The measurement results from the sensors are displayed on an Android application and stored in a logger. Functional test results indicate that all components used in the prototype monitoring system function normally, and the measurement errors are within the datasheet limits of each component. The percentage error values from the accuracy testing of the sensors show values below 5%, with the largest error being 3.2% in current measurement and the smallest error being 0.0% in distance measurement. Therefore, the sensors are in good condition, and these values are below the IEC 13B-23 standard limits.

Transformator distribusi merupakan komponen terpenting dari sistem distribusi tenaga listrik. *Output* nilai parameter tegangan, arus, suhu, ketinggian minyak bervariasi, sehingga diperlukan monitoring. Proyek akhir ini bertujuan untuk merancang bangun, mengetahui uji fungsional alat, mengetahui kinerja keakuratan komponen. Hasil rancang bangun sistem yang telah dilakukan menunjukan komponen yang digunakan pada sistem prototype adalah sensor INA219, AHT10, HC-SR04. Hasil pengukuran dari sensor ditampilkan pada aplikasi android serta tersimpan pada logger. Hasil uji fungsional menunjukan seluruh komponen yang digunakan pada alat prototype sistem monitoring dapat berfungsi dengan normal dan nilai error pengukuran sesuai dengan batas datasheet dari masing-masing komponen. Nilai persentase error pengujian keakuratan sensor menunjukan nilai dibawah 5% dengan nilai error terbesar pada pengukuran arus sebesar 3,2% sedangkan nilai error terkecil pada pengukuran jarak sebesar 0,0%, sehingga sensor dalam keadaan normal serta nilai tersebut dibawah batas IEC 13B-23.

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1. Introduction

Electrical energy plays an important role in human life, seen from the electricity consumption that continues to increase every year along with the increase in industrial buildings, commercial buildings, and residential buildings. This increase causes the demand for power to increase, so that the construction of distribution transformers as distributors of electrical energy flow from the generating system to consumers is increasing. The need for distribution transformers is increasing, but it is not balanced with an increase in the maintenance system of the distribution transformers [1]. Lack of maintenance and real-time monitoring of transformers can cause transformer failures such as over voltage, under voltage. Failure of the transformer function causes losses to both parties, both the consumer side and the electrical energy distributor side.

Distribution transformers are the most important components of the electrical power distribution system and have the function of increasing or decreasing voltage. Step down transformers is considered to have an important role in distributing electrical energy from 20kV medium voltage lines down to 380V or 220V voltage directly to electrical energy consumers [2]. If the transformer is in good health, the transformer can work optimally, and the output voltage of the electrical energy will be more stable and vice versa.

Distribution transformer monitoring is an activity carried out to obtain information related to the performance of the distribution transformer system in distributing electrical energy, the information obtained is used to determine disruptions or system repairs in the distribution transformer in the future. The reliability parameters of the distribution transformer system whose data information is not known in real time can cause unexpected failures and loss of supply to a large number of customers [3]. Monitoring is included in predictive maintenance or maintenance before damage occurs during system operation, system performance will be measured continuously.

Distribution transformer monitoring is still carried out manually using measuring instruments by visiting the location of the distribution transformer, this is still less efficient in terms of time and information related to monitoring results is limited. The monitoring process can be carried out remotely to reduce utility operating and maintenance costs so that it can increase the reliability of electricity services [4]. Telemetry-based technology allows data to be sent from two separate places via sensors, microcontrollers and wireless data transmission [5].

The monitoring process is needed to determine system performance so that there are no greater disruptions that can damage components and even cause system failures that lead to consumer losses. In addition, monitoring is useful for monitoring fluctuations in voltage, current, temperature, and oil volume values. Fluctuations in voltage, current, temperature, and oil volume values can be used as a reference for repairing or overcoming disturbances that occur [6]. Routine maintenance is considered unable to solve the problem of when disturbances occur in distribution transformers in real time. Based on these problems, the title of the final project was taken "prototype of voltage, current, temperature, oil level monitoring system in transformers" data collection on distribution transformers related to voltage, current, temperature, oil volume. In addition, this final project uses the Telemetry concept so that it can monitor the collection of information data on distribution transformers remotely and in real time. The data that has been taken is then processed until it gets mature data and can provide notification regarding the condition of the distribution transformer monitored via the internet web.

2. Methods

2.1 Electric Power Distribution System

The electric power system is part of the distribution of electric power sourced from power plants, substations to consumers [7]. A step-down distribution transformer is one of the equipment in the electric power distribution system. A step-down distribution transformer has the function of changing the flow of high-voltage electric power into a flow of low-voltage electric power with the same frequency. The transformer works by utilizing the principle of electromagnetic induction, namely the connection of the primary coil with an alternating voltage source, so that there is a change in current that triggers a magnetic field, then the magnetic field is strengthened with an iron core and flows to the secondary coil [8].

2.2 System Monitoring Transformer Step Down

Monitoring is the process of collecting data and maintaining several conditions of an object. Settings with monitoring systems can be designed to maintain and keep track of objects. Virtual monitoring systems provide information and conditions of all objects by analyzing and detecting other abnormal conditions [9]. Energy from the transformer should be less than the main syringe per transformer. Gangguan such as overload, overheat, under oil, over voltage and under voltage.

The transformer monitoring system provides a wide range of transformer conditions for increasing power from the transformer or increasing the conditions from the transformer by measuring the parameter values and assumptions, decreasing the volume and increasing the quality. Each of these parameters then processes for many normal or abnormal conditions of the realtime transformer. The height, height, height, and volume are the most important parameters of the power supply of the transformer [10].

2.3 Telemetry

Telemetry includes system features and features that should be checked from the beginning. The telemetry system consists of a large number of components consisting of two components namely transmitter and receiver. Transmitter includes part of a telemetry system that includes functions for increasing data parameter objects within a wide range of communications required. For example, this transmitter functions to receive signals if data that is not received should be analyzed efficiently. The receiver consists of a telemetry system that contains mending functions and uses data parameter object content that is received by the transmitter and then stored during the integration of the cellular data [11]. Adanya system telemetry can remember to determine the parameter object shape available with access data achieved to determine the temperature line [12].

2.4 Prototype

Prototype is an initial concept used as testing material for the real concept entity of a technology in the field of manufacturing and software engineering. Prototype is made as a production plan that represents the shape and dimensions of the initial concept object it represents [13]. The prototype that is built has a structure, function, and system operation that represents a simulation of the actual product. Using a prototype, technical problems on the actual tool that may arise can be identified and overcome, so that the actual tool can function properly.

2.5 Thunkable

Thunkable is one of the internet of things (IoT) support platforms based on the internet web. Thunkable can be used by new users to program computers as software application makers for Android and iOS operating systems. The program code for the Android system is created using a program system that has been created from the Thunkable platform so that program creation is only by dragging and dropping blocks [14].

2.6 Google Spreadsheet

Google spreadsheet is a program developed by Google with a function as a data processor. Google spreadsheet is widely used as an output companion in the form of a data recorder or data logger from IoT projects. Data entered into Google spreadsheet can be stored in cloud storage from Google [15].

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3. Designs

The concept of tool design is a discussion related to the stages and processes of the final project entitled Prototype of Voltage, Current, Temperature, and Oil Level Monitoring System in Transformers consisting of identification and analysis of needs, design and design of tools, tool manufacturing and tool testing. The following is described in the form of a tool manufacturing flow

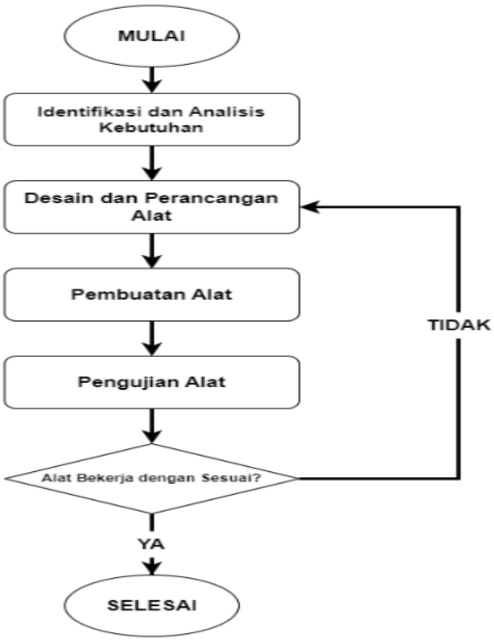

Fig. 1. Flowchart

Needs Analysis is a stage of analysis regarding the urgency of making a tool. This stage of needs analysis is by conducting field observations and literature studies. Field observations are carried out on routine maintenance of distribution transformers by PT. PLN. The process of monitoring transformers manually with hardware is considered less effective because it cannot be done in real-time. Therefore, a telemetry-based transformer monitoring system is needed that can monitor important parameters on transformers such as voltage, current, temperature, oil level. While the literature study conducted to find solutions to the existing problems is based on various literature. The literature obtained is in the form of articles obtained from various journals.

3.1 Flowchart

The following is a flowchart of the prototype monitoring system for voltage, current, temperature, and oil level in a transformer

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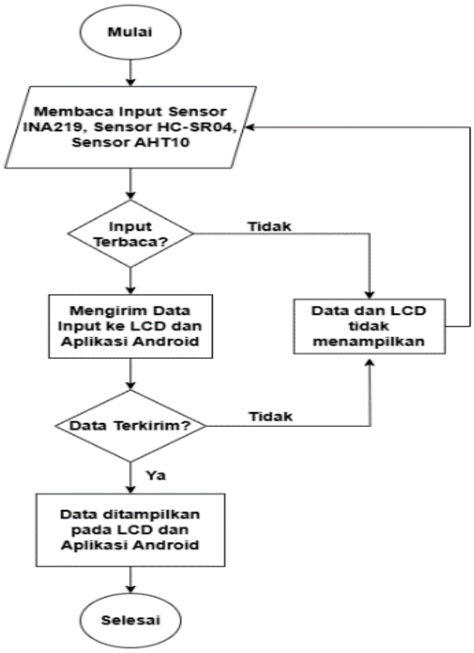

Fig. 2. Flowchart of the system

Figure 2 is a flowchart prototype of a monitoring system for voltage, current, temperature, and oil level in a transformer. Based on the system flowchart in Figure 2, the working process of the tool begins with reading the input of the INA219 sensor, AHT10 sensor, and HC-SR04 sensor. The system detects whether the input parameters from the transformer are read or not; if not read, the data on the monitoring will be empty and the system will reset, while if read, the parameters will be updated on the LCD and sent to the android application and 20x4 LCD. If the data is not sent, the monitoring display remains empty and the system performs re-detection. If sent, the data will be displayed on the android application and 20x4 LCD.

3.2 Hardware Design

The hardware manufacturing process consists of two parts including the creation of electrical design and the creation of mechanical design. Electrical design includes the creation of electrical wiring used in the system, while mechanical design includes the creation of physical design of the tool and the placement of components on the tool being made. The following are the results of the hardware design.

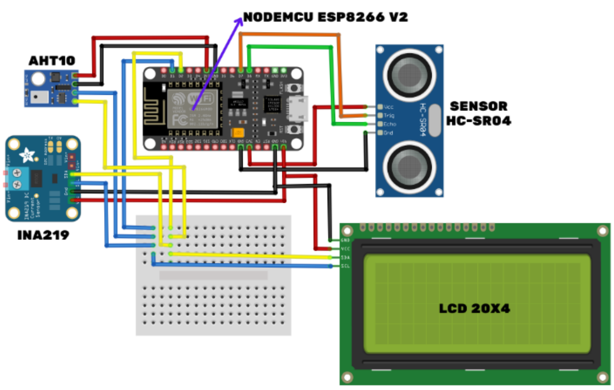

Fig. 3. Wiring components

Figure 3 is a wiring diagram of each component used in the monitoring system. The main components of the monitoring system used based on the image above are the INA219 voltage and

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current sensor, AHT10 temperature sensor, HC-SR04 distance sensor, 20x4 LCD, and NodeMCU ESP8266 microcontroller.

Fig. 4. Box design

Figure 4 is a box design image of a prototype monitoring system for voltage, current, temperature, and oil level in a transformer. The box is used to place electrical components used in the manufacture of the tool project.

3.3 Software Design

This stage is carried out to determine the process of making software designs used in the prototype monitoring system for voltage, current, temperature, and oil levels in transformers. The software design is divided into three stages, namely the stage of making programs on the NodeMCU ESP8266 microcontroller in the Arduino IDE application, making Android applications on Thunkable, and making Google spreadsheet programs on apps script.

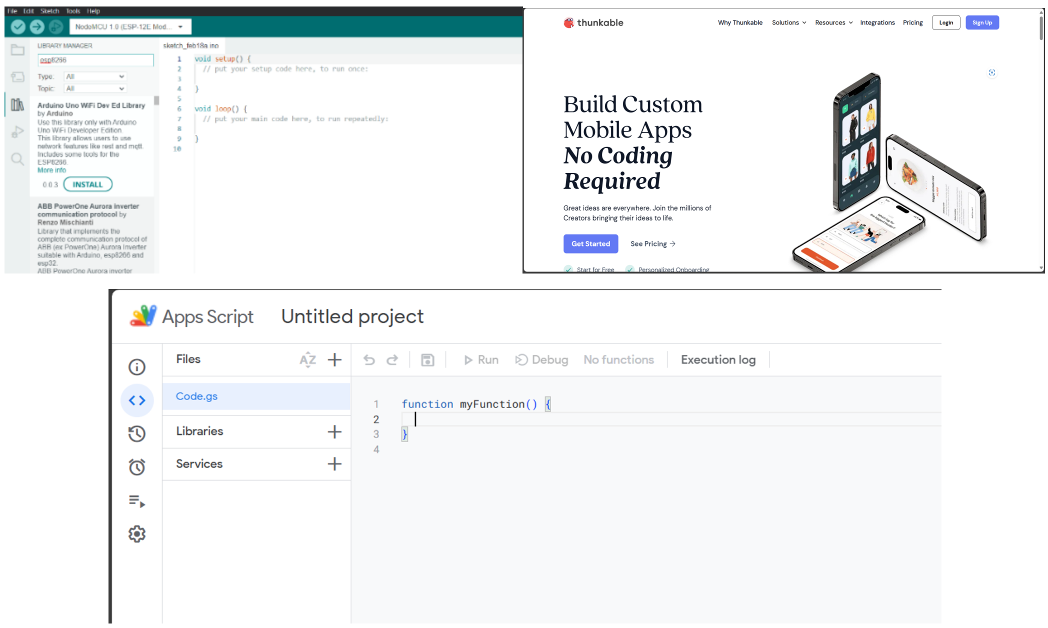

Fig. 5. Arduino IDE, Thunkable, and Apps Script

4. Results and Discussion

4.1 Hardware

The results of making hardware prototypes of voltage, current, temperature, and oil level monitoring systems on transformers consist of making electrical and mechanical systems. The electrical system is placed on a PCB so that the components are more organized and safe. After the installation on the PCB is complete, the PCB is placed in a box that has been made. The following is the display result of making electrical and mechanical systems on a box.

Fig. 6. Hardware Prototype

Figure 6 above is the result of making a hardware prototype of a monitoring system for voltage, current, temperature, and oil level in a transformer. Based on the image above, it can be seen that the front part has an LCD, 2 on-off load trigger switches, a voltage trigger potentiometer, and a push button reset button. For electrical components such as sensors, modules, and microcontrollers, they are in the monitoring system box.

4.2 Software

Software creation consists of three stages including creating an Arduino IDE program, creating an Android application, and creating a Google spreadsheet. The following are the results of creating a microcontroller program on the Arduino IDE application.

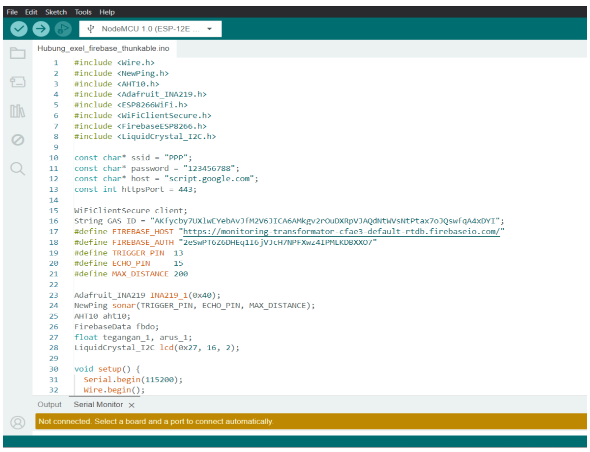

Fig. 7. Code Arduino IDE

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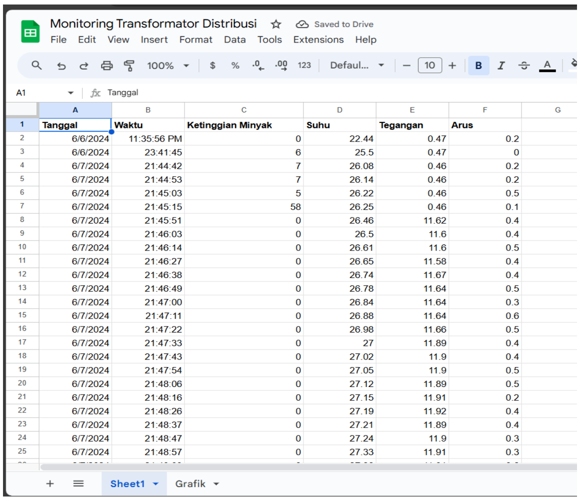
Figure 7 is a NodeMCU ESP8266 microcontroller program using the Arduino IDE application. The microcontroller is given a program so that it can receive input parameter values read by the sensor and can be processed, then sent to the android application and the value data is stored in a spreadsheet. The following is the result of the appearance of the android application that was successfully created.

Fig. 8. Android Application

Figure 8 is an android application that has been successfully created using the thinkable application. Then the last stage is the creation of a monitoring logger that is used to store incoming data. The following is a display of the monitoring logger that has been successfully created.



Monitoring Transformator Distribusi

	Tanggal	Waktu	Ketinggian Minyak	Suhu	Tegangan	Arus
2	6/6/2024	11:35:56 PM	0	22.44	0.47	0.2
3	6/6/2024	23:41:45	6	25.5	0.47	0
4	6/7/2024	21:44:42	7	26.08	0.46	0.2
5	6/7/2024	21:44:53	7	26.14	0.46	0.2
6	6/7/2024	21:45:03	5	26.22	0.46	0.5
7	6/7/2024	21:45:15	58	26.25	0.46	0.1
8	6/7/2024	21:45:51	0	26.46	11.62	0.4
9	6/7/2024	21:46:03	0	26.5	11.6	0.4
10	6/7/2024	21:46:14	0	26.61	11.6	0.5
11	6/7/2024	21:46:27	0	26.65	11.58	0.4
12	6/7/2024	21:46:38	0	26.74	11.67	0.4
13	6/7/2024	21:46:49	0	26.78	11.64	0.5
14	6/7/2024	21:47:00	0	26.84	11.64	0.3
15	6/7/2024	21:47:11	0	26.88	11.64	0.6
16	6/7/2024	21:47:22	0	26.98	11.66	0.5
17	6/7/2024	21:47:33	0	27	11.89	0.4
18	6/7/2024	21:47:43	0	27.02	11.9	0.4
19	6/7/2024	21:47:54	0	27.05	11.9	0.5
20	6/7/2024	21:48:06	0	27.12	11.89	0.5
21	6/7/2024	21:48:16	0	27.15	11.91	0.2
22	6/7/2024	21:48:26	0	27.19	11.92	0.4
23	6/7/2024	21:48:37	0	27.21	11.89	0.4
24	6/7/2024	21:48:47	0	27.24	11.9	0.3
25	6/7/2024	21:48:57	0	27.33	11.91	0.3

Sheet1 Grafik

Fig. 9. Logger Monitoring

4.3 Performance Testing

Performance testing is conducted to determine the accuracy of the parameters in the system compared to conventional measuring instruments. The parameters whose data are taken include voltage, current, temperature, oil level. Then the results of the comparison with the measuring instrument are compared with IEC (International Electrotechnical Commission) 13B-23 on electrical measuring instruments. The following are the results of the successful monitoring system accuracy test.

Table 1. Temperature testing

Time	Temperature		Error (C)	Percentage Error (%)	Status
	Sensor AHT10 (C)	Thermometer (C)			
7/29/2024 12:29:17	35.68	35.5	0.18	0,5	Safe
7/29/2024 12:29:32	36.47	36.2	0.25	0,7	Safe
7/29/2024 12:29:47	39.23	39.3	0.7	0,1	Safe
7/29/2024 12:30:02	43.65	43.8	0.15	0,3	Overheat
7/29/2024 12:30:17	45.87	45.2	0.67	1,4	Overheat
7/29/2024 12:30:32	48.42	48.6	0,18	0,3	Overheat
7/29/2024 12:30:47	53.41	54,1	0.69	1,2	Overheat
7/29/2024 12:31:02	57.48	58.3	0.82	1,4	Overheat
Average Error				0,74%	Accurate

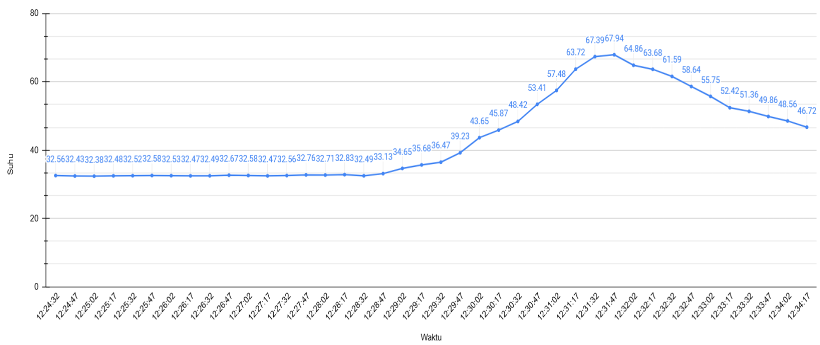


Fig. 10. Temperature Parameter Value Change Graph

Table 1 shows the results of the largest error value test, which is 1.4% when measuring temperatures of 57.48° and 45.87°, while the comparison of the smallest error value shows a value of 0.1%. The condition of the Android application shows that if the temperature is above 40°, it will provide an overheat check notification. The 2-minute test was carried out without adding temperature variations, the temperature (overheat) increased as the current value increased (overload). The results of the temperature increase value that was read were also displayed on the graph generated by the spreadsheet logger as in Figure 10. This shows that the sensor accuracy value is still in good condition.

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Table 2. Voltage Testing

Time	Trigger (V)	Voltage		Error (V)	Percentage Error (%)	Status
		Sensor INA219 (V)	Multimeter (V)			
7/29/2024 12:26:32	6	6.43	6.32	0.11	1,7	Undervoltage
7/29/2024 12:26:47	8	8.23	8.38	0.15	1,7	Undervoltage
7/29/2024 12:27:02	10	10.36	10.25	0.11	1	Safe
7/29/2024 12:27:17	12	12.26	12.39	0.13	1	Safe
7/29/2024 12:27:32	14	14.38	14.28	0.1	0,7	Overvoltage
7/29/2024 12:27:47	15	15.68	15.60	0.08	0,5	Overvoltage
7/29/2024 12:28:02	16	16.82	16.72	0.1	0,5	Overvoltage
7/29/2024 12:28:17	17	17.52	17.46	0.06	0,3	Overvoltage
Average Error					0,92%	Accurate

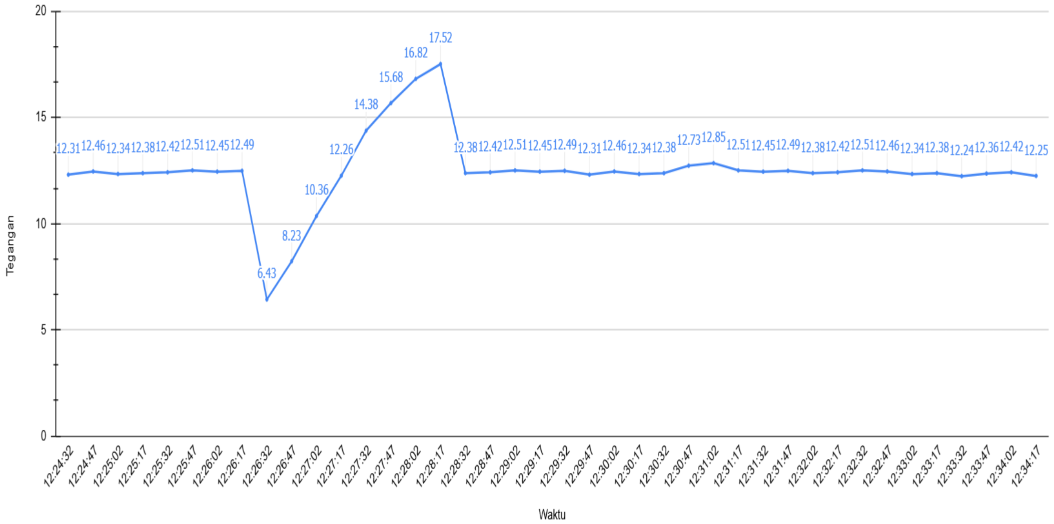

Fig. 11. Voltage Parameter Value Change Graph

Table 2 shows the results of the largest error value test, which is 1.7% when measuring the 6V and 8V voltage triggers, while the comparison of the smallest error values shows a value of 0.3%. The condition of the Android application shows that if the voltage is above 14V, it will provide an overvoltage check notification, while below 10V it will provide an undervoltage check notification. Then 2 minutes are added to the voltage variation value to produce an overvoltage or undervoltage condition. The results of the voltage increase value that is read are also displayed on the graph generated by the spreadsheet logger as shown in Figure 11. This shows that the sensor accuracy value is still in good condition.

Table 3. Current Testing

Time	Voltage (V)	Resistance (Ω)	Current		Error (mA)	Percentage Error (%)	Status
			Sensor INA219 (mA)	Ampere Meter (mA)			
7/29/2024 12:28:32	12	5 W 22	540	545	5	0,9	Safe
7/29/2024 12:28:47		5 W 22	545	550	5	0,9	Safe
7/29/2024 12:29:02		5 W 22	542	560	8	3,2	Safe
7/29/2024 12:29:17		5 W 22	538	545	7	1,2	Safe
7/29/2024 12:29:32		5 W 15	786	800	14	1,7	Overload
7/29/2024 12:29:47		5 W 15	794	800	6	0,7	Overload
7/29/2024 12:30:02		5 W 15	792	800	8	0,1	Overload
7/29/2024 12:30:17		5 W 15	804	800	4	0,5	Overload
Average Error						1,15%	Accurate

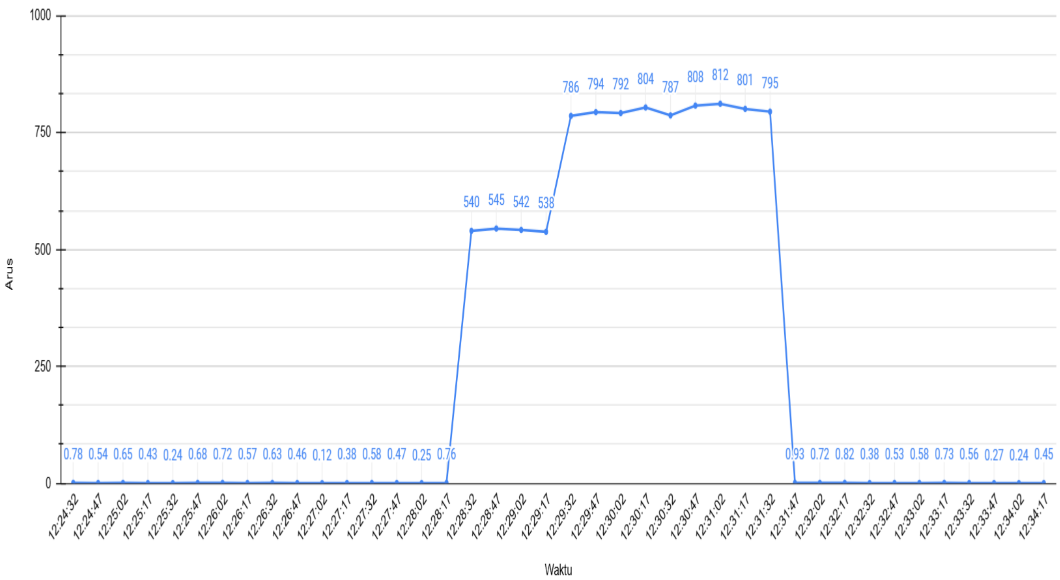

Fig. 12. Current Parameter Value Change Graph

Table 3 shows the results of the largest error value test, which is 3.2% when measuring a current of 542 mA with a 5W 22 Ω resistor load, while the comparison of the smallest error value shows a value of 0.1%. The condition of the Android application shows that if the current is above 600 mA, it will provide an overload check notification. The third 2-minute test was carried out by adding load variations 1 and load variations 2, resulting in an overload condition caused by excessive load. The results of the increase in the read current value are also displayed on the graph generated by the spreadsheet logger as in Figure 12. This shows that the sensor accuracy value is still in good condition.

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Table 4. Distance Testing

Time	Distance (cm)	Measurements		Error (cm)	Percentage Error (%)	Status
		Sensor HC-SR04 (cm)	Vernier calipers (cm)			
7/29/2024 12:32:32	5	5	5	0	0,0	Safe
7/29/2024 12:32:47	6	6	6	0	0,0	Safe
7/29/2024 12:33:02	7	7	7	0	0,0	Safe
7/29/2024 12:33:17	8	8	8	0	0,0	Safe
7/29/2024 12:33:32	10	10	10	0	0,0	Safe
7/29/2024 12:33:47	12	12	12	0	0,0	Under Oil
7/29/2024 12:34:02	13	13	13	0	0,0	Under Oil
7/29/2024 12:34:17	14	14	14	0	0,0	Under Oil
Average Error					0,0%	Accurate

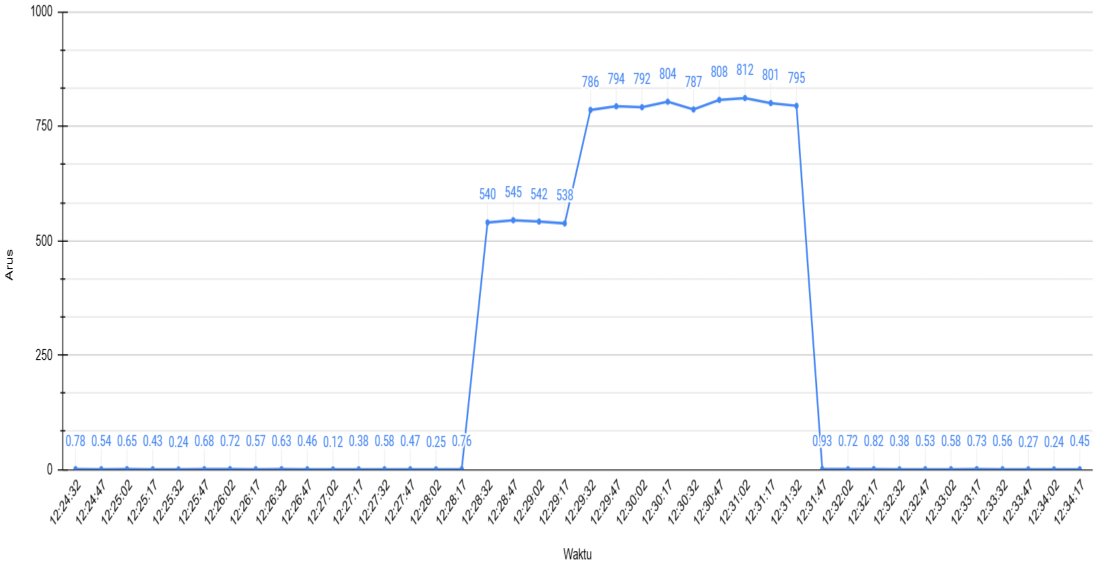

Fig. 13. Distance Parameter Value Change Graph

Table 4 shows the results of the largest error value test, which is 0.0%, while the comparison of the smallest error value shows a value of 0.0%. The condition of the Android application shows that if the temperature is above 10 cm, it will provide an underoil check notification. The 2-minute test was carried out by adding variations in oil height to produce an under oil condition. The results of the increase in the read distance are also displayed on the graph generated by the spreadsheet logger as in Figure 13. This shows that the sensor accuracy value is still in good condition.

Table 5. LCD Testing Comparison with Android Application

Time	LCD				Android Apps				Error	Results
	V (V)	I (mA)	Temp (C)	Distance (cm)	V (V)	I (mA)	Temp (C)	Distance (cm)		
7/29/2024 12:24:32	12.31	0.78	32.56	5	12.31	0.78	32.56	5	0,00	Accepted
7/29/2024 12:24:47	12.46	0.54	32.43	5	12.46	0.54	32.43	5	0,00	
7/29/2024 12:25:02	12.34	0.65	32.38	5	12.34	0.65	32.38	5	0,00	
7/29/2024 12:25:17	12.38	0.43	32.48	5	12.38	0.43	32.48	5	0,00	
7/29/2024 12:25:32	12.42	0.24	32.52	5	12.42	0.24	32.52	5	0,00	
7/29/2024 12:25:47	12.51	0.68	32.58	5	12.51	0.68	32.58	5	0,00	
7/29/2024 12:26:02	12.45	0.72	32.53	5	12.45	0.72	32.53	5	0,00	
7/29/2024 12:26:17	12.49	0.57	32.47	5	12.49	0.57	32.47	5	0,00	
7/29/2024 12:26:32	6.43	0.63	32.49	5	6.43	0.63	32.49	5	0,00	
7/29/2024 12:26:47	8.23	0.46	32.67	5	8.23	0.46	32.67	5	0,00	
7/29/2024 12:27:02	10.36	0.12	32.58	5	10.36	0.12	32.58	5	0,00	
7/29/2024 12:27:17	12.26	0.38	32.47	5	12.26	0.38	32.47	5	0,00	
7/29/2024 12:27:32	14.38	0.58	32.56	5	14.38	0.58	32.56	5	0,00	
7/29/2024 12:27:47	15.68	0.47	32.76	5	15.68	0.47	32.76	5	0,00	
7/29/2024 12:28:02	16.82	0.25	32.71	5	16.82	0.25	32.71	5	0,00	

The test results were obtained by directly testing the tool made using variations found in the prototype tool for monitoring voltage, current, temperature, and oil level in the transformer. The time taken for the test was 10 minutes with data collection every 15 seconds. The parameter values taken include voltage, temperature, current, and oil level distance. Based on table 5 above, the parameter results displayed on the android application and LCD are the same.

5. Conclusion

Voltage and current parameters are measured on the system using the INA219 sensor component, temperature parameters are measured on the system using the AHT10 sensor component, oil level parameters are measured on the system using the HC-SR04 sensor component. Sensor measurement data is processed using the NodeMCU ESP8266 microcontroller. The processed data is sent and displayed on the android application and 20x4 LCD using a WiFi network. Performance test results from the prototype system of voltage, current, temperature, oil level monitoring system on the transformer. The results obtained that the sensor accuracy is in accurate

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condition because the average error value is 0.74%, 0.92%, 1.15%, 0.0% between system measurements and measuring instruments below 5%. So according to IEC 13B-23 the measurement accuracy value on the prototype system is in accurate condition and can display notification results on the android application. The results of the tool performance test show that the system can function according to plan, namely displaying monitoring results from the android application and storing monitoring data in the spreadsheet logger

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