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SMART MONITORING OF DISTRIBUTION TRANSFORMERS: VOLTAGE, CURRENT, AND GAS DETECTION VIA IOT

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Article Info

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Abstract

The distribution network plays a vital role in electricity distribution but is susceptible to various disturbances that can jeopardize its performance and damage distribution transformers. Safety devices and voltage breakers are commonly used to address disturbances, but they may fail to provide adequate protection during temporary network disruptions. Such disturbances can lead to fluctuations in voltage, current, temperature, and gas levels in the distribution transformer. To address these challenges, the implementation of a reliable monitoring system becomes crucial. Monitoring, as an observation activity with a specific purpose, has evolved with the advancement of technology. The Internet of Things (IoT) has emerged as a wireless telecommunications technology that enables objects and devices to communicate with each other. IoT-based monitoring systems have shown promise in remote monitoring applications, exemplified by smart metering for real-time monitoring and control of public services like electricity, water, and gas consumption. This research revolves around the development of a monitoring system for distribution transformers, focusing on the measurement of voltage unbalance, overload, current unbalance, and distribution transformer oil temperature. The study also delves into monitoring methane and hydrogen gas levels in the distribution transformer, which are critical indicators of potential issues. The proposed system integrates sensors like ZMPT101B for voltage readings, SCT013-00 for current measurements, and DS18B20 for temperature monitoring.

The project's main objective is to create a novel "Voltage, Current, Temperature Monitoring System, Methane, and Hydrogen Gas Levels in Distribution Transformers Based on the Internet of Things." With this system, monitoring operations can be conducted from a distance, ensuring convenience and flexibility. The sensor readings exhibit a high level of accuracy, with an error margin of only ± 1.8% when compared to a digital multimeter. Additionally, the research introduces a new measurement approach that utilizes the Blynk platform, enhancing accessibility and speed of the process.

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The paper also draws inspiration from related research on IoT, which allows users to monitor electricity consumption without the need to be physically present at the location. Building upon these findings, the authors aim to design a microcontroller-based "Electrical Energy Monitoring and Control System in Boarding Rooms based on the Internet of Things (IoT)." The system aims to empower power users by providing real-time data on electricity consumption in boarding rooms, enabling efficient consumption management and savings.

1. Introduction

The distribution network is an integral part of electricity distribution which is very vulnerable to disturbances. This disturbance should be resolved as soon as possible so that it does not interfere with the performance of the electricity distribution and also damage the distribution transformer. It uses safety devices and voltage breakers in each load area to overcome disturbances. However, the protection system cannot provide security if there is a temporary network disturbance. The effects of this disturbance are changes in voltage, current, temperature, and gas levels in the distribution transformer.

Monitoring is an activity that aims to observe an object with a specific purpose. The technology that can be applied in building a monitoring system is increasingly advanced and developing. The Internet of Things (IoT) is a technology in the field of wireless telecommunications that utilizes objects or other devices to communicate with each other. The current use of IoT has also borne fruit in remote monitoring. One example of the everyday use of IoT is smart metering which can control and monitor the use of public services such as electricity, water, gas bills, and others in real-time through applications installed on cell phones.

Based on IEC standards for temperatures with an annual average of 20℃ and a daily average of 30℃ in general, the life of the distribution transformer is reached, and the capacity decreases to 91% of its everyday life. According to SPLN, a transformer is overloaded when the transformer load exceeds 80% of the transformer capacity (nameplate) or the nominal current (In). Then the gas content in the distribution transformer is reviewed from the standard IEEE C57.104 Total Dissolved Complicated Gas (TDCG), explaining that the main gas content problem in the transformer is the gas produced due to rising temperatures in the distribution transformer oil cooler. One example is methane gas produced due to an increase in relative temperature of 150℃ [4].

Previously, research had been carried out with a distribution transformer monitoring system based on Xbee Pro. This study describes monitoring distribution transformers by monitoring voltage unbalance, overload, current unbalance, and distribution transformer oil temperature. This research has been carried out by obtaining voltage readings using the ZMPT101B sensor, present with the SCT013-00 sensor, and temperature using the DS18B20 sensor.

Based on the explanation that has been explained, there are main problems that inspired the author to conduct research in the form of a thesis entitled "Voltage, Current, Temperature Monitoring System, Methane and Hydrogen Gas Levels in Distribution Transformers Based on the Internet of Things." Enabling this monitoring system to operate from any distance. Sensor readings show error accuracy. Sensor measurement results show an error accuracy of ± 1.8% compared to a digital multimeter. From the results of the research that has been done, the authors came up with a new idea in the measurement stage, namely monitoring electrical energy using the Blynk platform to make the measurement process more accessible and make it faster and more flexible [4].

Related research has been carried out using the Internet of Things (IoT), created by Kevin Ashton, executive director of the Auto-ID Center, MIT, in 1999. A device can transmit data over a network without using a computer or human device and can be accessed via long distance; with the IoT system, a user can monitor electricity consumption without going directly to the location [6].

From these problems, the authors are interested in conducting research that aims to monitor and obtain sources of information on the use of electrical energy in boarding rooms. This monitoring tool is based on a microcontroller. In addition, this monitoring tool is also based on IoT so that power consumption can be monitored directly and remotely with real-time output results. This design the author made with the title "Electrical Energy Monitoring and Control System in Boarding Rooms based on the Internet of Things (IoT)." The tool created by the author aims to help power users to provide information on the amount of electricity consumption consumed in boarding rooms and to help power users save on their consumption.

2. Literature Review

2.1. Transformer

In its simplest form, a transformer consists of two isolated coils coupled to a standard or mutual magnetic field generated in a core of magnetic material. The coil connected to the alternating current source is named the primary coil, and the coil connected to the load is called the secondary coil [7]

2.2. Gas Levels in Transformer

The emergence of dissolved gas in the transformer is often an early indication of a disturbance that may occur. Factors that can cause these disorders include the amount of water, acid, etc. [8]. The presence of propane (C_2H_8), propylene (C_3H_6), and butane (C_4H_8) gases do not include gases that have an essential effect on the transformer. However, these gases can be detected and identified in dissolved gas testing. At the same time, gases that include combustible gases include hydrogen (H_2), methane (CH_4), ethane (C_2H_6), ethylene (C_2H_4), acetylene (C_2H_2), carbon dioxide (CO_2), and carbon monoxide (CO), as shown in Table 1[9].

Table 1. Maximum gas content in the transformer

No	Gas Content	Maximum Limit
1.	Hydrogen	100 ppm
2.	Methane	120 ppm
3.	Acetylene	1 ppm
4.	Ethylene	50 ppm
5.	Ethane	65 ppm
6.	Carbon Monoxide	350 ppm
7.	Carbon Dioxide	2500

2.3. Internet of Things (IoT)

The Internet of Things (IoT) is a concept where an object can transfer data over a network without requiring human-to-human or humanto-computer interaction [10]. IoT uses several technologies to expand internet network connectivity, including connecting equipment, machines, and other objects using network sensors and actuators to obtain data, regulate their performance, and produce automated work processes.

2.4. NodeMCU

NodeMCU ESP8266 is a development derivative module from the ESP8266 type ESP-12 IoT platform module. Functionally, this module is almost similar to the Arduino module platform, but the difference is that it is dedicated to connecting to the internet. There are several I/O pins so that it can be developed into a monitoring and control application for IoT projects [13]. The NodeMCU module used is version 1.0.

2.5. PZEEM-004t

The PZEM-004T sensor is hardware that measures voltage, current, active power, frequency, power factor, and vibrant energy, a module without a display function. Data is read through the TTL interface [14]. The PZEM-004T board measures 3.1 × 7.4 cm. The PZEM-004T module is bundled with a 3mm diameter current transformer coil, which can measure a maximum current of 100A. The wiring of this module has two parts, namely, the wiring of the voltage and current input terminals, as well as the serial communication wiring. Based on requirements, this module has a TTL pin board to support serial data communication between hardware. The following is the shape of the PZEM-004T sensors. The TTL interface of this module is passive, requiring an external 5V power supply [15]. To connect the module, the two ports between the load and the process must be combined, and if the port is not connected, it cannot communicate.

2.6. DS18B20

DS18B20 is a temperature sensor where the temperature value and measurement speed accuracy have much better stability than the LM35DZ temperature sensor. The DS18B20 sensor has waterproof capabilities. The DS18B20 sensor is a digital sensor that has an internal 12-bit ADC. Very precise because if the reference voltage is 5 Volts, then due to temperature changes, it can feel the minor difference of $5/(2^{12}-1) = 0.0012$ Volts. In the temperature range of -10 to +85 degrees Celsius, this sensor has an accuracy of approximately 0.5 degrees. This sensor uses a 1-wire (one-wire) communication protocol [17]. The standard deviation is used when the data is extensive and has a dispersion of the average value so that the value of Sx will be significant. Still, if the data has a shallow distribution of the average value, the standard deviation value will be low.

2.7. MQ-4

MQ-4 is a stable semiconductor sensor with high sensitivity to gas. The sensitivity of the MQ-4 sensor that can be read or detected is methane gas which will later produce analog signal data. MQ-4 sensors generally have a reasonably simple driver circuit. Besides that, the MQ-4 sensor is composed of micro aluminum oxide (Al_2O_3) ceramic tube and tin dioxide (SnO_2), a sensitive layer, and a small series used in the sensor. MQ-4 consists of 6 pins, 4 of which are responsible for signaling, while the remaining two pins are responsible for responding to combustion or heating that occurs,

The MQ-4 sensor has an operating voltage of 0.2V to ± 5.0 V AC/DC. The concentration that the sensor can read is 300 to 1000 ppm where the gas that can be read is natural gas and methane. It has a heater resistance of 5Ω to ± 33Ω, while the heater consumption is ≤750mW [19]. In addition, the heating time can be 24 hours. The sensor work system is generally the same, where the sensor will produce analog data. The physical form of the MQ-4 sensor, note Figure 4.

2.8. MQ-7

The MQ7 sensor is a gas sensor used to detect carbon monoxide (CO) gas [4]. The feature of the MQ7 gas sensor is that it has high sensitivity to carbon monoxide (CO), is stable, and has a long service life. The structure and configuration of the MQ7 gas sensor can be seen in Figure 5. The material for making the sensor consists of micro AL_2O_3 as a ceramic tube, zinc (SnO_2) as a layer for the sensor, the electrode and heater are covered with plastic and a protective shield is made of stainless steel in the form of a net at the top of the sensor. Prevent corrosion inside the sensor. The heater is used to helping sensor performance sensitivity when needed.

2.9. MQ-8

The MQ-8 sensor is a gas sensor that determines the concentration of hydrogen gas (H). It has high sensitivity and fast response time. The output generated by the MQ-8 gas sensor is in the form of an analog signal. This sensor also requires a DC voltage of 5V[16]. Measurement range from 100-10000 ppm concentration to measure Hydrogen gas. This sensor has a resistance value (Rs) that can change when exposed to gas and a heater that is used to clean the sensor room from outside air contamination. The MQ-8 gas sensor requires a simple circuit and needs a heating voltage (power heater) of 5V. load resistance and sensor output are connected to an analog-digital converter (ADC) so that the result can be displayed in the form of a digital signal. Of course, as a measurement tool, the MQ-8 sensor requires calibration so that the measured gas is appropriate. There are 2 comparison calibration data in previous studies, the first is the MQ-8 sensor calibration data with the measured gas being 99% pure Hydrogen gas and the second is the MQ-7 sensor calibration data with the measured gas being Carbon Monoxide gas in vehicles [20].

3. Methods

3.1. System Block Diagram

The system block diagram presented at this point contains connected component blocks, as shown in Figure 1 below.

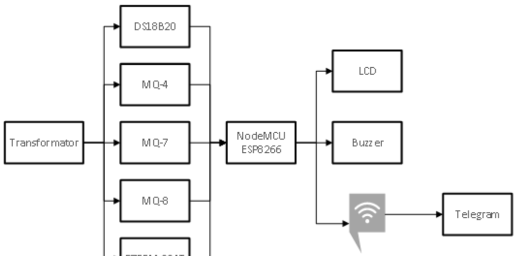

Fig 1. Block Diagram

3.2. Design Circuit

All assembled components are connected to the NodeMCU ESP8266. NodeMCU ESP8266 will process all members according to the desired program. Based on the picture, the VCC pin on all components is red, and this pin will be connected to the NodeMCU ESP8266 3V pin. While the GND pin will be connected to the NodMCU ESP8266 Gnd pin, as shown on the black line. Equations should be numbered consecutively throughout the paper. The equation number is enclosed in parentheses and placed flush right, as in (1). Your equation should be typed using the Times New Roman font (please, no other font). To create multilevel equations, it may be necessary to treat the equation as a graphic and insert it into the text after your paper is styled.

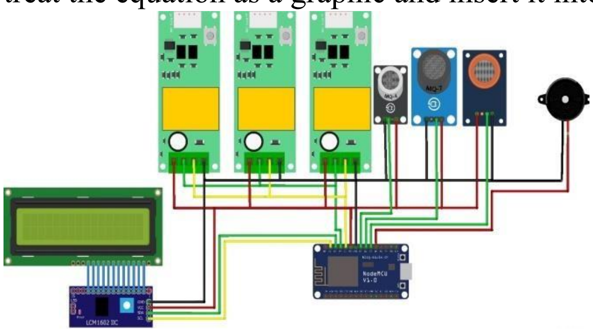

Fig 2. Design Circuit

4. Results and Discussion

4.1. Testing the PZEM-004T sensor voltage

The voltage test results were carried out to see the accuracy of the PZEM-004t sensor. This test is carried out by comparing the sensor values displayed on the LCD with a volt meter. The test is carried out using an autotransformer with a variable voltage. For more details, see Figure 3, Testing the PZEEM-004t sensor voltage.

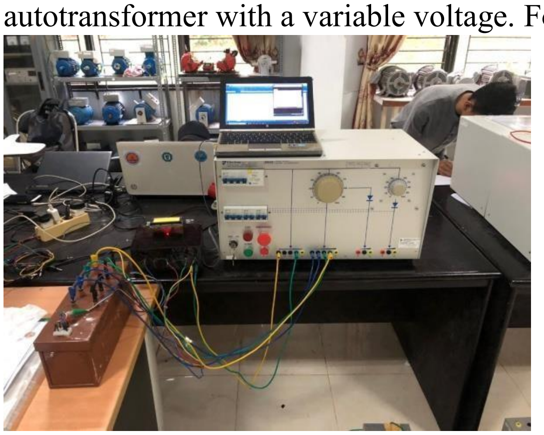

Fig 3. PZEEM-004t sensor voltage test

Table 2 The results of the voltage test on the PZEM-004T sensors

No.	Voltage (V)	Phase	Measuring Instrument (V)	PZEM-004T Sensors (V)	Error (%)

		R	80,4	80,3 80	0,1
		S	80,2	80,4	0,2
		T	80,2		0,2
			Average		0,2
			SD value		0,1
		R	120,1	120,2	0,1
		S	120,2	120,1	0,1
	80	T	120,4	120,9	0,5
1	120		Average		0,2
2			SD value		0,2
4		R	200,4	201,2	0,8
5	200	S	200,2	200,8	0,6
	240	T	201,3	202,9	1,6
			Average		1,0
			SD value		0,5
		R	241,5	242,5	1,0
		S	241,8	242,1	0,3
		T	242,2	243,3	1,1
			Average		0,8
			SD value		0,4

4.2. Test Current Sensors

The current sensor is tested to determine the error in the present value measured using the PZEM-004T sensor. Tests are performed by comparing the values calculated using an amperage meter with the PZEM-400T sensor. Autotransformer is a power source using a load whose value can be changed.

Table 3 The results of the current test on the PZEM-004T sensors

No.	Beban (Ω)	Phase	Measuring Instrument (A)	Sensor PZEM004T (A)	Error
		R	1,2	1,13	0,07
		S	1,21	1,17	0,04
		T	1,21	1,13	0,08
			Average		0,06
1	200		SD value		0,02
3	300	R	0,71	0,68	0,03
		S	0,72	0,68	0,04
		T	0,72	0,71	0,01
			Average		0,03
			SD value		0,02

R 0,29 0,22 0,07 5 850 S 0,25 0,27 0,02

	T	0,25	0,29	0,04
Average				0,04
SD value				0,03

4.3. Test DS18B29 Sensors

Testing the DS18B20 sensor is done by comparing the value of the measuring instrument with the sensor to find the error value when measuring temperature. The measuring device used is a thermometer with units of Celsius. The test results can be seen in Table 4.3 DS18B20 sensor test results.

Table 4. The results of the temperature test on the DS18B20 sensors

Test	Temperature (°C)	Measuring Instrument (°C)	Sensor DS18B20 (°C)	Error
1	46	46,3	46,19	0,11
2	42	42,5	42,15	0,35
3	38	38,1	38,07	0,03
4	34	34,2	34,25	0,05
5	30	30,5	30,54	0,04
		Average		0,12
		SD value		0,13

4.4. Test Gas Sensors

The results of the gas sensor test are tests carried out to measure CH4, CO, and H2 gas levels. Each gas was measured using the MQ-4 sensor for CH4 gas, the MQ-7 sensor for CO gas, and the MQ-8 sensor for H2 gas. In testing this sensor, measuring tools are not used to compare sensor values. So that the characteristic values for each sensor are used in the datasheet so that the equation for determining gas levels is obtained. The gas sensor test results can be seen in Table 5 Gas sensor test results.

Table 5. The results of the test gas sensors

	MQ-4		MQ-7		MQ-8	
No.	Vout (V)	CH-4 (PPM)	Vout (V)	CO (PPM)	Vout (V)	H2 (PPM)
1.	0,51	104,35	0,70	143,36	1,40	286,44
2.	0,52	106,39	0,83	169,82	1,41	288,49
3.	0,53	108,44	0,95	194,37	1,42	290,53
4.	0,54	110,48	1,06	216,88	1,43	292,58
5.	0,55	112,53	1,38	282,35	1,44	294,62

4.5. Test OverAll

The overall test is a test carried out using all components. This test aims to determine the performance of the tool that was designed. Then use a load whose resistance value can be changed to resemble events in the field. Look at Table 6. Overall test results data.

Table 6. Overall test results data.

No.	Phase R			Phase S			Phase T			Transformer condition			
	R (Ω)	V (V)	I (A)	R (Ω)	V (V)	I (A)	R (Ω)	V (V)	I (A)	Temperature (°C)	CH4 (PPM)	CH7 (PPM	CH8 (PPM
1	460	64,5	0,14	313	64,8	0,22	186	63,8	0,35	25,1	90	18,2	120,3
2	236	65,8	0,28	158	65,5	0,42	186	64,5	0,36	27,3	94,3	18,9	120,4
3	186	66,1	0,35	158	66,5	0,42	313	65,6	0,21	28,8	96,3	19,3	139,4
4	158	67,2	0,42	313	65	0,21	186	64,1	0,36	29,8	108,7	21,2	144,8

5	313	66,5	0,21	460	66,2	0,14	158	65,1	0,42	30,1	113	21,7	158

Based on the table above, five trials were carried out in the overall test. The test is carried out by changing the load value, in which the loading conditions are unbalanced for each phase. In the first experiment, phase R used a load of 460 Ω with a voltage of 64.5V and a current of 0.14A was obtained. At the same time, the S phase uses a pack of 313 Ω, a voltage of 63.8V, and a current flowing of 0.22A. And phase T uses a load of 63.8V with a load of 186 Ω and a flowing current of 0.35A. In the first experiment, the transformer temperature was 25oC with a CH4 level of 25.1PPM, a CO level of 18.2 PPM, and an H2 level of 120.3PPM.
The overall experiment found that if the temperature of the transformer increases, the gas content also increases. This increase in temperature is due to the amount of energy used by the load and also due to the load imbalance that occurs. This experiment also found that the highest temperature reached was 30.1oC with a CH4 gas content of 113PPM, a CO gas content of 21.7PPM, and an H2 gas content of 158PPM.

5. Conclusion

The conclusions drawn from this study are as follows.

1. A monitoring system for voltage, current, temperature, methane, and hydrogen gas levels in an Internet of Things-based distribution transformer can measure the transformer's voltage, current, temperature, and gas content.
2. At the time of testing, it was found that due to the unbalanced load conditions, there was an increase in temperature in the transformer, which resulted in changes in gas levels. From the test, it was found that the lowest gas content was CH4 reaching 113 PPM, CO ran at 21PPM, and H2 got 158PPM.

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