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Power Usage Monitoring and Overload Protection System for Distribution Transformers

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A B S T R A C T

Efficient energy manitoring and overload protection on distribution transformers are very much needed. This study aims to develop a power usage management system and overload protection integrated with Internet of Things (IoT) technology, with a specific target to monitor and manage power usage on distribution transformers in real time, as well as provide automatic protection against overload conditions. The methodology used in this study involves the design and implementation of hardware and software that supports wireless communication and data analysis. This system is also equipped with a power reading and protection mechanism that can automatically cut off the electricity flow when an overload detection occurs, in order to prevent damage to the transformer, it is expected that this system can increase the efficiency of power usage management and provide a quick response to overload conditions. The implementation of this system is expected to reduce operational costs and increase the reliability of electricity supply on the distribution network. Based on the tests that have been carried out, it has been proven that the system has worked well in maintaining important variables in the power usage management system and overload protection on the Internet of Things integrated distribution transformer.

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INTRODUCTION

Distribution transformers are important components in the power distribution system, which function to distribute electrical energy from the transmission network to end consumers with the appropriate voltage. The efficiency and reliability of distribution transformers are very important to maintain the continuity and quality of electricity supply. However, in its operation, transformers often face challenges such as overloads that can cause serious damage, service disruptions, and high repair costs (Gultom, Cholish, & Sitepu, 2022).

Along with the increasing energy needs and the complexity of the distribution network, effective power usage management and overload protection are becoming increasingly crucial. Conventional technologies are often unable to provide a fast and accurate response to changes in load conditions, which can result in less than optimal power usage and an increased risk of damage to the transformer (Tondok, Patras, & Lisi, 2019).

The Internet of Things (IoT) offers an innovative solution to this problem through real-time data collection, data-driven analysis, and automatic control. By utilizing smart sensors and wireless communication, IoT can monitor various transformer operational parameters such as current, voltage, and temperature, and send the data to a central system for analysis. This data analysis allows early identification of abnormal conditions such as overload, so that protective actions can be taken automatically to prevent damage (Istiana, 2022).

This research focuses on the development of a power usage management system and overload protection integrated with IoT for distribution transformers. This system is designed to improve energy efficiency, reduce the risk of damage, and improve the reliability of electricity supply. With the implementation of IoT technology, it is hoped that this system can provide an effective and efficient solution in overcoming operational challenges in distribution transformers.

Based on the background above, the researcher sees the need to implement a Power Usage Management System and Overload Protection on an Integrated Internet of Things Distribution Transformer to read the power usage of each Phase, be it phase R/L1, phase S/L2 and phase T/L3, power factor, transformer operating temperature, overload protection and its duration as well as notification of power usage when there is an overload on the Internet Of Things (IoT) based distribution transformer as remote real-time control and monitoring.

LITERATURE REVIEW

In this modern era, the demand for electrical energy continues to increase along with population growth and technological developments. Distribution transformers, as key components in the electricity distribution network, must be able to handle increasingly complex and diverse loads. Excessive loads on transformers can cause overheating, decreased efficiency, and even permanent damage. Therefore, an efficient power usage management system and reliable overload protection are needed to ensure the reliability and efficiency of transformer operations (Soedjarwanto & Nama, 2019).

A. Power Usage Management and Overload Protection

Distribution transformers are devices used to step down the voltage from a high transmission network to a level that can be used by end consumers. The main function of a distribution transformer is to ensure that electricity can be distributed safely and efficiently to various consumer areas. The efficiency and reliability of transformers are critical to maintaining continuity of electricity supply and avoiding service disruptions. These transformers must be able to handle significant load variations, which can cause overheating and damage if not managed properly (Sogen, 2018).

Power usage management is the process of managing electricity usage to ensure that energy distribution is carried out efficiently and according to needs. In the context of distribution transformers, power usage management involves continuous monitoring of current, voltage, and temperature to ensure that the transformer is operating within safe limits. The main objectives of power usage management are to optimize transformer performance, reduce energy waste, and minimize the risk of failure due to overload (Shodiq, Baqaruzi, & Muhtar, 2021).

Overload protection is a mechanism designed to protect transformers from damage caused by electric currents that exceed safe capacities. Overloads can occur due to sudden increases in electricity demand or due to abnormal operating conditions. Overload protection systems typically involve the use of relays and circuit breakers that will automatically cut off the flow of electricity when an overload is detected. The purpose of overload protection is to prevent overheating, insulation damage, and potential transformer failure (Anugerah Putra, 2021).

B. Overall Sensor Control System

The control system to drive all sensor work uses Arduino as an electronic device that functions like a microcontroller and is open source. Arduino has a processor from the Atmel AVR family. Arduino has software with a specific programming language. The Arduino board has the ability to read digital - analog data input and output digital - analog data. Arduino programming is supported by the IDE (Integrated Development Environment) so that it becomes a fun and widely used programming (Setiawardhana, 2019). There are many types of Arduino boards available on the market with designs that are tailored to various applications. The Arduino board is a printed circuit board (PCB) designed to use a microcontroller chip and other inputs and outputs. The board has many other electronic components needed for the microcontroller to function or to expand its capabilities (Banzi & Shiloh, 2022).

C. System Input and Output

The input and output of this system are used to provide a visible work of the Power Usage Management System and Overload Protection on the

Integrated Distribution Transformer Internet of Things so that it can be analyzed and evaluated. The system input used is the PZEM-004T Module which is used to read the power usage of each Phase, be it phase R/L1, phase S/L2 and phase T/L3, MCB as an overload protection system that has been adjusted, for the system output using a sound indicator from the buzzer which is used to find out the condition of the system while working (Satria, 2023).

METHODOLOGY

In the research of Power Usage Monitoring System and Overload Protection on Distribution Transformers combines hardware and software parts, where the hardware consists of mechanical design and electronic requirements design. While the software part consists of programming needs such as sensor work algorithms and application feature needs from the monitoring process. Flow of Power Usage Monitoring System and Overload Protection on Distribution Transformers, where problems arise due to uncalculated power usage, unhandled overload protection, no monitoring and management of power usage on distribution transformers with real-time remote monitoring so that a system that has been adjusted is needed such as methods and systems, such as software algorithms that must be appropriate, good hardware installation and the existence of a power management system and overload protection on distribution transformers, if the system is running then testing of the designed system can be carried out such as testing system parameters and monitoring system parameters. The research design that will be carried out can be seen in the Overall System Design Diagram below:

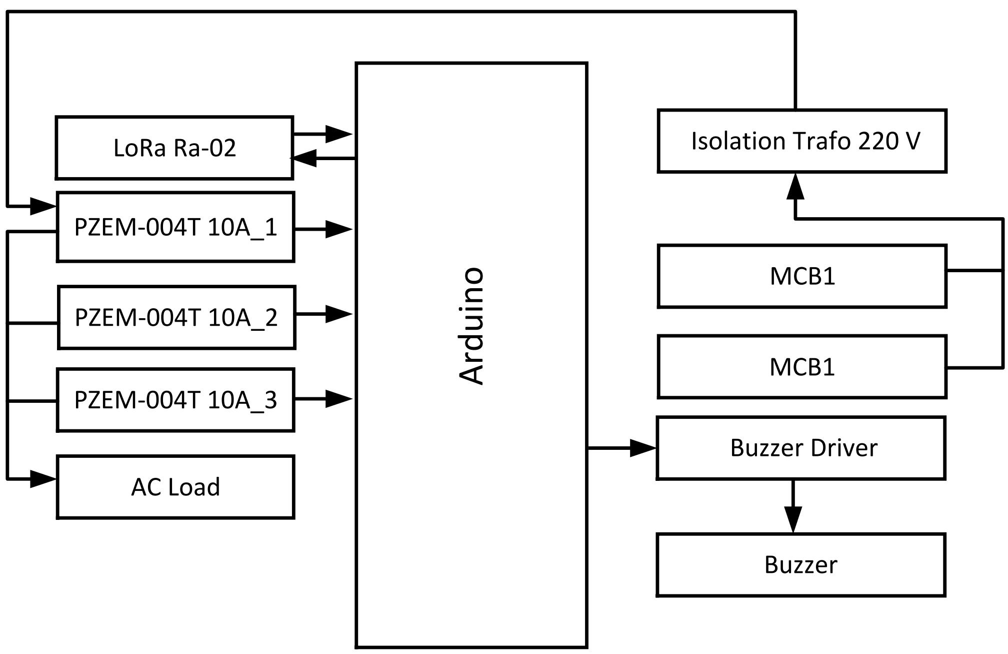

Figure 1. Research Design Diagram for The Entire System

In the image above, the system works as a transmitter where there is communication between the wireless system network using LoRa Ra-02 with the aim that if one of the networks is constrained, the reading and monitoring of incoming signals will continue, in the transmitter block there are three PZEM-004T modules as modules to read the power consumption of each phase, both phase R / L1, phase S / L2 and phase T / L3 against the AC load used, the isolation transformer as a distribution transformer is tasked with lowering the voltage from the substation to a lower level, so that it can be distributed to consumers. The use of electricity in distribution transformers needs to be monitored continuously to determine their operational conditions and so that timely maintenance or repairs can be carried out, MCB 1 and MCB 2 function as overload protection against power consumption in distribution transformers and there is a buzzer that functions as a location indicator in the form of sound to determine the condition of the system that is running. The second block functions as a receiver block that is used as communication for each data reading to the system (using LoRa) and the user's cellphone (using an IoT-based internet network) to display the monitoring results that can be read, both the power usage readings for each phase, both phase R / L1, phase S / L2 and phase T / L3, power factor, transformer operating temperature, overload protection and its duration, as well as notification of power usage and overload on the distribution transformer.

The stages of implementing the research begin with conducting a literature study regarding supporting references for the research, references for the use of components needed in the implementation of the system, after obtaining references, the determination and design of the mechanics and circuit modules needed by the system are carried out, such as the mechanical design to be made, the need for circuit modules, some of which are controllers, sensors and circuit modules used such as indicator displays and wireless modules, after the mechanical design and circuit modules are carried out, testing will be carried out to ensure that all mechanical designs and circuit modules can work properly. Then continue by connecting the entire series according to system needs, continued with software design by creating a program algorithm, then after the program algorithm is complete, it is continued to upload it to the controller as the input and output control center, the next stage is testing the tool, ensuring the designed system is appropriate or not, if there are still problems, they will be repaired again according to the problems that occur, but after it is in accordance with the research, the stage of working on/creating the system design has been completed, continued with data collection, report preparation and publication.

RESEARCH RESULT

The results and discussion of the research on the Power Usage Monitoring System and Overload Protection on Distribution Transformers consist of two tests, namely testing the power usage monitoring system on distribution transformers against the load and testing the current disconnection (trip) on the load.

A. Testing the power usage monitoring system on distribution transformers against loads

Testing the power usage management system on distribution transformers is an effort to ensure efficiency and reliability in measuring electrical energy usage. Distribution transformers play an important role in distributing energy from the main electricity network to end consumers. With the power usage management system, energy consumption can be monitored so that power losses can be minimized, and transformer performance can be monitored better. This test aims to evaluate the extent to which the system is able to manage the measurement of power usage used. The loads used as test loads are 5 Watt Lamps, 50 Watt Fans and 350 Watt Rice Cookers. The results of testing the power usage management system on distribution transformers can be seen in Table 1 as follows.

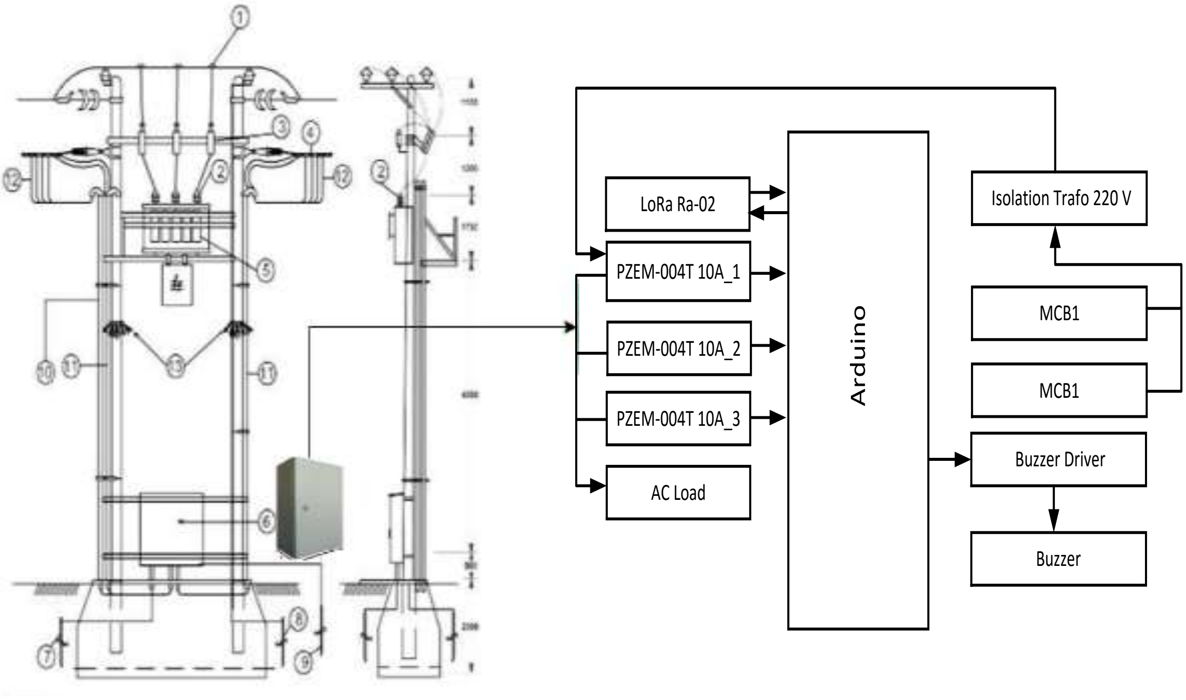

Figure 2. Design of Power Usage Monitoring System on Distribution Transformers

Table 1. Testing of power usage monitoring system on distribution transformers

Load	Testing	Phase R			Phase S			Phase T		
		V	I	P	V	I	P	V	I	P
Lamp	1	223	0,04	8,92	222	0,04	8,88	222	0,04	8,88
	2	222	0,07	15,54	221	0,07	15,47	221	0,07	15,47
	3	221	0,1	22,1	220	0,1	22	220	0,1	22
Fan	1	217	0,14	30,38	216	0,14	30,24	215	0,14	30,1
	2	215	0,14	30,1	216	0,14	30,24	215	0,15	32,25

	3	215	0,15	32,25	214	0,15	32,1	215	0,15	32,25
Rice Cooker	1	222	0,17	37,74	222	0,17	37,74	221	0,17	37,57
	2	216	1,57	339,12	217	1,58	342,86	216	1,57	339,12
	3	221	1,33	293,93	219	1,55	339,45	215	1,45	311,75

From the tests shown in Table 1, the data obtained shows the results of power usage from each phase, namely R, S and T, for each load and is well monitored by the designed system.

B. Current disconnection (trip) test on the load

Current disconnection (Trip) test on the Load is one of the important procedures in the electrical system that aims to ensure the protection and safety of electrical devices when there is an excess current or abnormal conditions. This test is carried out to verify whether the circuit breaker or other safety device can effectively disconnect the flow of electric current on a certain load when the current exceeds a predetermined threshold. This disconnection is necessary to prevent damage to equipment, fire risks, or other electrical accidents. The loads used as test loads are 5 Watt Lamps, 50 Watt Fans and 350 Watt Rice Cookers. The results of the Current disconnection (Trip) Test on the Load can be seen in Table 2 as follows.

Table 2. Current disconnection (Trip) Test on the Load

Load	Testing	Voltage (Volt)	Current (A)	Power (Watt)	Load Conditions
Lamp	Testing 1 (1 Lamp)	222	0,04	8,88	On
	Testing 2 (2 Lamp)	221	0,07	15,47	On
	Testing 3 (3 Lamp)	220	0,16	35,2	Off
Fan	Testing 1 (Level 1)	217	0,14	30,38	On
	Testing 2 (Level 2)	215	0,14	30,1	On
	Testing (Level 3)	215	0,15	32,25	On
	Testing 4 (Level 3 + Lamp 1)	215	0,16	34,4	Off
Rice Cooker	Testing 1 (Level Warm)	222	0,17	37,74	On
	Testing 2 (Level Cook)	217	1,57	340,69	On
	Testing 3 (Level Cook + lamp 1)	216	1,6	345,6	Off

From the test shown in Table 2, the data obtained shows that the trip current disconnection on the load, both lights, fans and rice cookers, is set at 0.16 A, so that if the load is added beyond the setting current, the system will trip so that the load is in an inactive status.

DISCUSSION

This system allows real-time management of electrical power usage, so that energy usage is more efficient. This helps reduce energy waste and minimize operational costs. Overload protection applied to this system can prevent transformers from damage due to loads exceeding their capacity. With this system, transformers will be automatically protected to maintain their stability and safety. With an integrated management system, electrical power distribution becomes more reliable because disturbances such as overload can be immediately detected and resolved. This increases the reliability of electricity supply to consumers, knowing the design of an automatic protection system that can detect and respond to overload conditions quickly to prevent damage to transformers and how to develop effective algorithms for data analysis to detect abnormal conditions in distribution transformers.

CONCLUSIONS AND RECOMMENDATIONS

This research has successfully developed an effective and efficient power usage management system on distribution transformers by utilizing monitoring technology. With real-time monitoring and control, this system is able to reduce energy waste and improve transformer operational efficiency. The integrated overload protection system is able to detect overload conditions quickly and provide an automatic response to protect the transformer from damage. This improves the safety and reliability of the transformer, as well as reducing the risk of equipment failure that could potentially cause a power outage. By monitoring the condition of the transformer, operators can detect potential problems early, so that preventive measures can be taken proactively. This contributes to improving the reliability of electricity distribution and minimizing downtime due to technical disturbances, allowing continuous and centralized data collection, providing valuable information on the performance and condition of the transformer in the long term.

ADVANCED RESEARCH

The research design on the power usage management system and overload protection on distribution transformers can be done in the use of more complex variables, further development, such as increasing sensor accuracy, integration with other power control systems, and utilizing artificial intelligence technology for better prediction of power usage patterns and overloads, this power management and protection system can be further developed by integrating into a broader energy management system, further tested on a larger scale, such as in various types of transformers and different environmental conditions. Trials at various locations with varying load and climate conditions can provide more representative results and help in improving the system for various power distribution scenarios. more focused on power efficiency settings, processed with computerization (computer vision) and can be implemented on an industrial scale.

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