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Overload Monitoring and Warning System for 3-Phase Electric Motorcycle based on IoT

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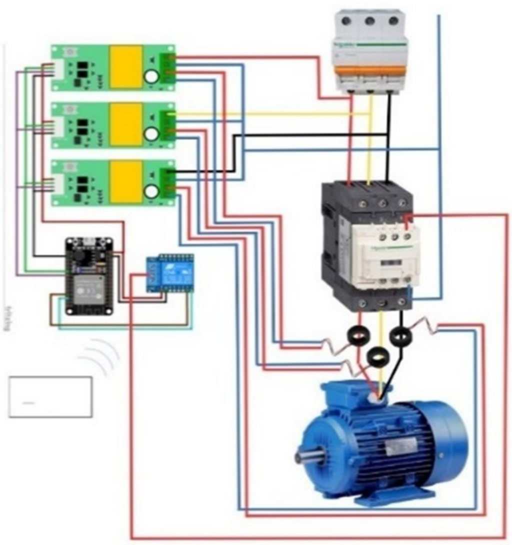
ABSTRACT



This research aims to develop and test a Telegram-based monitoring and overload warning system for three-phase motors, utilizing the PZEM-004T sensor and ESP8266 WiFi microcontroller, which is able to measure electrical parameters such as current, voltage, and power in real-time. The method used is a quantitative approach with an experimental method, where this system provides automatic notifications via the Telegram application in the event of an overload with a current limit of 20A, and is able to automatically cut off electricity to prevent more serious damage. Given the risk of overload that can cause production damage and costly downtime to the industry, the results show the effectiveness of the system in recording data and detecting overload conditions, although there are power measurement discrepancies that indicate the need for further calibration. Recommendations from this research include developments to improve measurement accuracy, standardization of procedures, and integration with relevant industry standards, as well as additional trials with different load variations to validate the system's performance in various scenarios.

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1. INTRODUCTION

An electric motor is a type of machine that uses electricity to generate motion energy, which re-generates rotary motion on the motor shaft [1][2]. One of the commonly used variants of AC motors is the induction motor, which is also known as an asynchronous motor [3]. The term “asynchronous” refers to the difference between the rotation speed of the motor shaft and the stator magnetic field. In other words, there is a speed difference called slip between the rotor rotation and the magnetic field, which is why these motors are called asynchronous [4].

With the increasing use of three-phase motors in industry, various problems have arisen in the field. Despite being equipped with a protection system, electrical panels still have the potential to be damaged [5][6]. Some of the causes of electrical panel damage are short circuit, overheating, or overloading [7][8]. One common problem is how to provide protection in the event of a fault that requires the motor to stop suddenly, including protection for the motor itself, the load being run by the motor, and the safety of the operator [9][10]. This kind of protection is known as emergency stopping, therefore, with the advancement and use of technology, the source of electrical energy can be controlled according to the needs and desires of the user [11][12].

The importance of using three-phase electric motors in a wide range of industrial and commercial applications carries the risk of overloading which can lead to serious damage and costly production downtime [13][14]. Overload Relay / Thermal Relay Overload relay is a device that opens or closes the contacts on the contactor if the current exceeds a predetermined limit [15][16]. It is an electrical control component whose job is to cut off the flow of electricity if the load exceeds a safe limit [17][18]. To overcome this risk, the need for a monitoring system that can monitor the condition of motor three-phase in real-time is becoming increasingly important [19][20]. Advanced sensors and monitoring technology allow the system to detect potential overloads early, enabling timely countermeasures to prevent damage [21][22].

Protection of three-phase motors is very important to prevent damage or unwanted events that can endanger the system [23][24]. To overcome this risk, the need for a monitoring system that is able to monitor the condition of the motor in real-time is becoming increasingly relevant [25][26]. Several previous studies have developed Internet of Things (IoT)-based systems and advanced sensor technologies to monitor motor voltage, current, and load conditions [27][28]. For example, some studies have demonstrated the ability of IoT systems to detect phase imbalances or overloads that can cause significant damage to motors [29][30].

To overcome these risks, the need for a monitoring system that can monitor the condition of motor threee-phase in real time is becoming increasingly important [31]. Using advanced sensor and monitoring technology, the system is able to respond to early warnings of potential overloads, so that appropriate precautions can be taken before damage occurs [32][33].

This research proposes an IoT-based monitoring system that integrates advanced sensor technology with machine learning to proactively detect anomalies [34][35]. The system also utilizes the Telegram app as a real-time notification platform, allowing technicians to receive alerts instantly, anytime and anywhere [36][37]. With this approach, the system is expected to overcome the limitations of previous research, such as slow response to changes in motor conditions or lack of reliable predictive analysis [38][39].The proposed system is designed to support predictive analysis using machine learning models.

This enables early identification of signs of potential damage, such as phase imbalance or abnormal current surges [40][41]. IoT technology that has been integrated with network-based systems makes a significant contribution in making monitoring easier, so that technicians or operators can take immediate action before problems develop into more serious ones [42][43]. One of the breakthroughs proposed in this research is the implementation of a monitoring system, which enables predictive analysis to detect early signs of potential damage to the motor [44]. This predictive analysis aims to provide proactive solutions in motor maintenance management, reducing the risk of downtime and extending equipment life [45][46].

This research makes significant contributions by filling gaps in the existing literature. First, by utilizing more integrated IoT technologies and more advanced machine learning, the system is expected to improve the accuracy and efficiency of anomaly detection. Secondly, the system offers a more user-friendly interface through integration with popular apps such as Telegram, thus improving responsiveness and ease of use [47][48]. By combining these technologies, this research focuses on overcoming the drawbacks of previous systems, such as limitations in early detection or slow response to changes in motor conditions. Therefore, this research is important to improve the effectiveness of induction motor monitoring and protection, while offering a more efficient solution in industrial asset management.

2. METHODS

This research uses a quantitative approach with experimental methods can be seen in Figure 1. The aim is to test the performance of the overload monitoring and warning system on the developed 3-phase electric motor panel, using the Telegram platform as a warning medium. The experimental procedure begins with the problem identification stage to identify the needs and parameters of the overload monitoring system on the 3-phase electric motor panel [49]. Followed by literature study to collect references related to monitoring systems and integration with the telegram platform [50]. The device design stage includes circuit schematic design, component selection, and communication system architecture design. Then at the tool making stage, hardware assembly, microcontroller programming, and integration with Telegram Bot are carried out. The last stage is Tool Testing which includes sensor calibration, and communication testing.

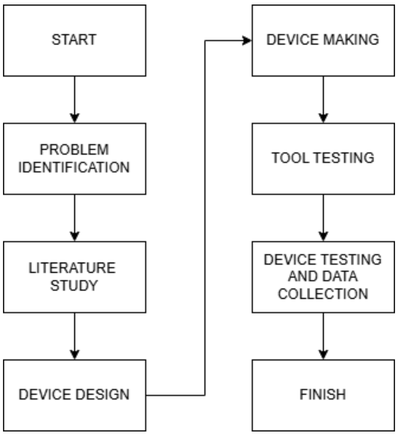


Figure 1. Block diagram of the System

2.1. Problem Identification

Problem identification was carried out by observing the importance of developing a more sophisticated monitoring and protection system for three-phase electric motors, especially in an industrial context that requires high reliability and operational efficiency.

2.2. Literature Study

A literature study was conducted to obtain the basic concepts of the hardware and software working systems of the proposed tool. Some of the concerns are the hardware design process using a combination of available electronic components. While the software design process uses a combination of electronic components available on the market. The literature taken comes from several scientific journal articles and scientific seminars. Figure 2 shows the system design block diagram. The system consists of a PZEM-004t that measures electrical parameters such as voltage, current, and power. The data from the PZEM-004t is then sent to the ESP8266 WiFi microcontroller which produces AC voltage and AC current readings in accordance with the measuring instrument standards. If the voltage read on one of the voltage phases is 190 V and the current exceeds 19 A or the voltage exceeds 240 V and the current read is normal around below 19 A with the provisions in the program being run, the relay will automatically order the switch to turn off.

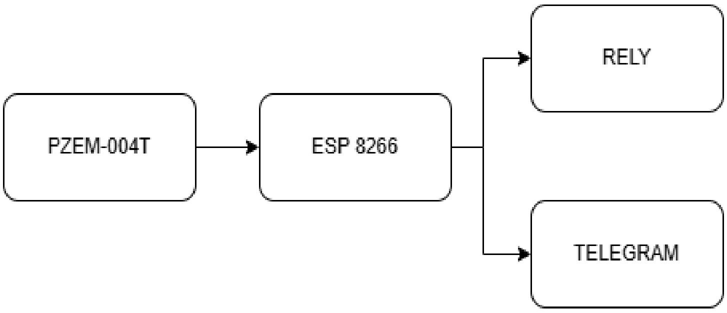


Figure 2. System design diagram image

2.3. System Design

In general, the flow is from the microcontroller collecting data from sensors and motor status, then sending it as a notification or report via Telegram. This enables remote monitoring and control of the operation of the motor and the system as a whole. From Figure 3, an explanation of the device monitoring system is obtained. The following is an explanation of the above circuit:

The system is designed to automatically control and monitor a three-phase electric motor. The electric current from the three main phases passes through a circuit breaker, then is controlled by a contactor. Three PZEM-004T modules are installed to detect the voltage and current on each phase, the data of which is sent to the microcontroller for analysis. If the microcontroller detects an overload, a relay is activated to cut the power to the contactor, so the motor will shut down to prevent damage. In addition, the microcontroller sends real-time motor condition data to the Telegram app, allowing users to receive notifications regarding the voltage, current, and status of the motor. The system improves safety with early detection of overloads and makes it easy to monitor and maintain the motor remotely. To ensure the PZEM-004T sensor functions accurately, a calibration process is required. Calibration is done by adjusting the voltage value on the regulator until it reaches the appropriate three-phase voltage by connecting each PZEM-004T sensor to each phase (R, S, T) on a three-phase motor.

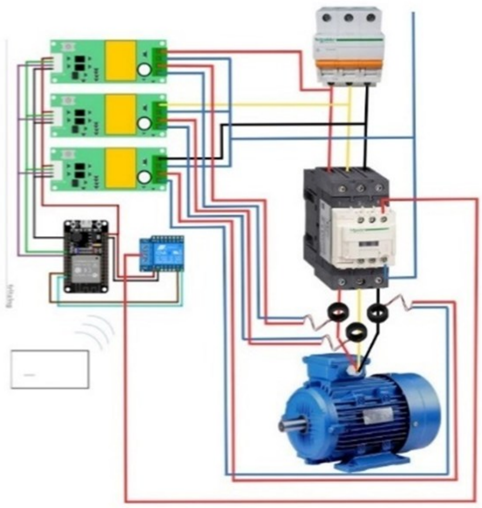
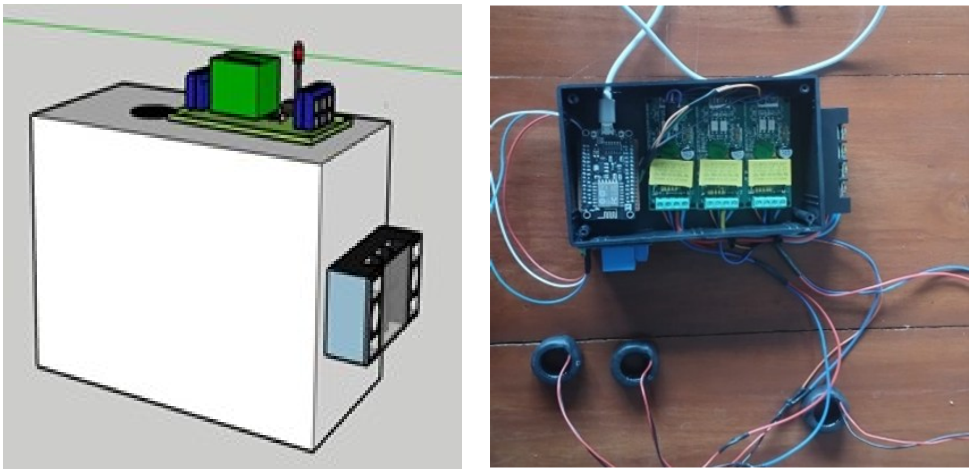


Figure 3. Circuit pictures

3. RESULT AND DISCUSSION

3.1. Prototype Design

The 3D design of the Telegram-based overload monitoring and warning system for 3-phase electric motors is based on the design concept that has been made. The following are the different 3D de-design images used for the monitoring and overload warning system for 3-phase electric motors can be seen in Figure 4.



(a) (b)

Figure 4. (a) 3D design of Telegram-based overload monitoring and warning, (b) Prototype of Telegram-based overload monitoring and warning tool

3.2. Designing a More Telegram-based Load Monitoring and Warning System

This tool has been refined with the results of existing designs can be seen in Figure 5. Telegram-based overload monitoring and warning system can be implemented using Pzem-004T sensor, microcontroller with

WiFi connectivity, and Telegram bot integration. The system is designed to measure electric current in real-time, calculate power, and send alerts via Telegram when the load exceeds the specified threshold. The relay will cut off the voltage source connected to A1 on the contactor so that the circuit will automatically stop and notify that the current exceeds 20A can be seen Figure 6.

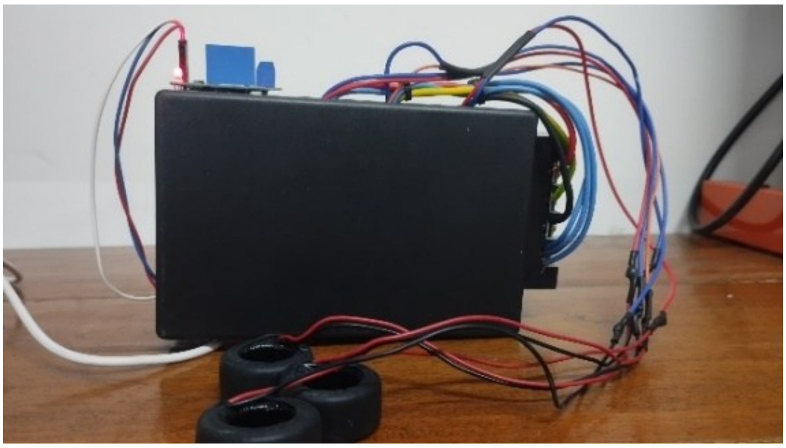


Figure 5. Telegram-based load monitoring and alert tool

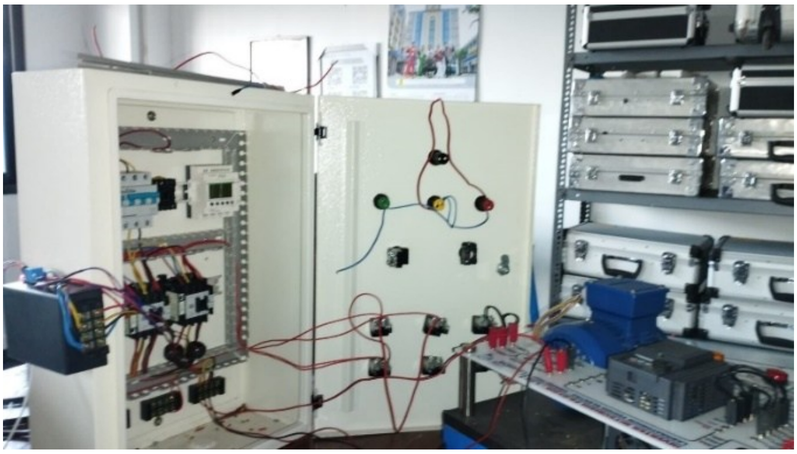


Figure 6. Tool installation position

The development of a measurement and safety circuit for electric motors using the Pzem-004T begins with the preparation of the main components, including the Pzem-004T, safety relays, contactors, and electric motors, as well as the RST cable for three-phase connection. The next step is voltage measurement, where the RST cable is connected to the input of the Pzem-004T before it enters the motor connector, allowing a reading of the voltage of the circuit at work. For current measurement, the Pzem-004T sensor is attached to the RST cable going to the electric motor, with the cable passed through the sensor loop to get an accurate reading.

The configuration of the safety relay is done by connecting it to the output of the Pzem-004T and setting it to cut off the electrical circuit at the voltage source connected to A1 on the contactor if an unsafe condition is detected. Integration with Telegram enables remote monitoring, with the Pzem-004T configured to send the reading data to the app. Afterward, system testing was conducted to ensure all components were functioning properly, including verification of voltage and current readings on Telegram as well as safety relay function tests.

The final stage involves calibration and adjustment, where the Pzem-004T is calibrated where necessary to improve the accuracy of the readings, and the threshold settings on the safety relays are adjusted according to the motor specifications and safety needs. By systematically implementing this circuit, real-time monitoring of voltage and current via Telegram is possible, as well as automatic protection via safety relays connected to contactors, ensuring safe and efficient operation of electric motors. Figure 7 is the monitor condition on Telegram. Telegram is a communication platform that can be used to control hardware, display, process, store, and visualize readable sensor data. In this experiment, we can see the respective RST readings of voltage, current, and power.

Figure 7. Telegram monitoring

3.3. Results

This research uses a quantitative approach with an experimental method to test the performance of the overload monitoring and warning system on the developed 3-phase electric motor panel, with the Telegram platform as a warning medium. Functional tests were conducted to evaluate the system's ability to monitor current, voltage, and power in real-time, and compare the results with measurements using a standard tool, namely a multimeter.

Testing of the Telegram-connected monitoring system was carried out by recording the voltage, current, and power on phases R, S, and T can be seen in Figure 8. The voltage on all three phases was relatively stable, with small fluctuations, ranging from 229.6 V to 239.3 V. The measured current was also consistent, ranging from 1.00 A to 1.14 A on all phases. The measured currents were also consistent, ranging from 1.00 A to 1.14 A on all phases. However, the power measurements indicated a load imbalance, with phase T recorded as having significantly lower power (36 W to 44.5 W) compared to phase R (222.4 W to 235.9 W) and phase S (189.6 W to 200.2 W) can be seen in Table 1.

Multimeter measurements were also taken on the R, S, and T phases with the same parameters: voltage, current, and power can be seen in Figure 9. The voltage measured through the multimeter showed similar stability to the Telegram measurements, ranging from 229 V to 238 V. The current measured was within the same range, ranging from 0.99 A to 1.14 A. However, the current measured was within the same range. The current measured was within the same range, between 0.99 A and 1.14 A. However, the power measured through the multimeter showed a more even distribution among the three phases. In phase T, the power recorded ranged from 258.5 W to 271.32 W, which is higher and more balanced compared to the measurement via Telegram can be seen in Table 2.

From the Figure 10 results of the difference between the two measurement results there is a slight difference in voltage and current R, S, T and for wattage has a very large difference in power R and T due to the tolerance of the pzzem 004T sensor reading which is less precise with the multitester measurement results can be seen in Table 3.

From the test results, it can be concluded that the Telegram-connected monitoring system is able to record electrical parameters well, especially for voltage and current, which show consistency in both measurement methods. However, there is a significant difference in the power measurement, where the Telegram-connected system records a large power imbalance in phase T, while the measurement using a multimeter shows a more even and balanced power distribution. This difference could be due to the calibration of the monitoring system or differences in the measurement method. Therefore, recalibration and further testing are required to ensure the accuracy and reliability of the system, especially in terms of power measurement can be seen in Figure 11.

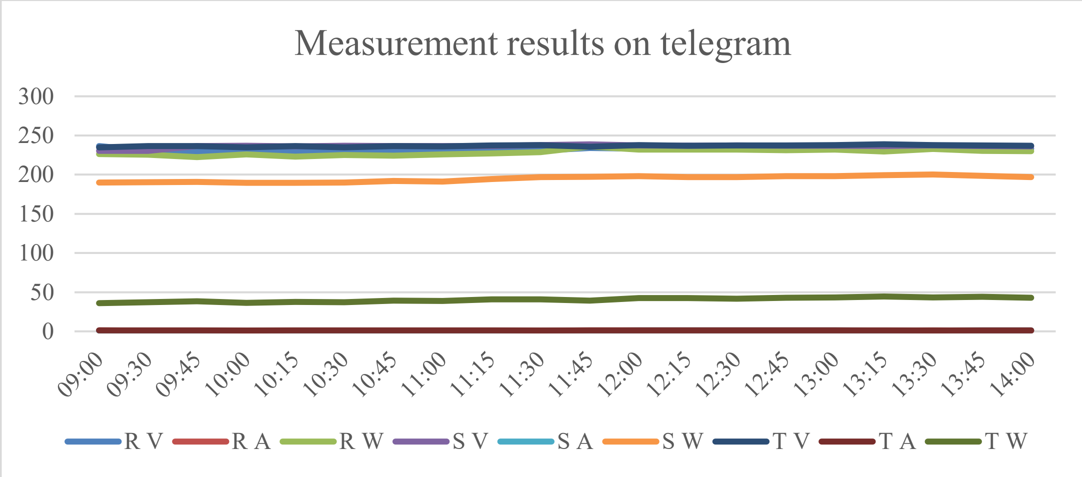


Figure 8. Graph Measurement results on telegram

Table 1. Measurement results on telegram

Time	R			S			T		
	V	A	W	V	A	W	V	A	W
9:00	236.4	1.3	226.4	230.4	1	190	234.8	1.11	36
9:30	230.5	1.03	225.4	230.5	1	190.3	236.6	1.11	37
9:45	229.6	1.01	222.4	236.3	1.01	190.8	236.5	1.11	38.4
10:00	230.6	1.02	226	236.7	1	189.6	234.9	1.1	36.5
10:15	229.7	1.02	223.2	236	1.01	189.6	236.3	1.11	35.4
10:30	230.5	1.02	225.2	236.9	1	190	235	1.11	37.1
10:45	230	1.02	224.2	236.5	1.01	191.8	236.6	1.12	39.1
11:00	231.1	1.02	226	236.3	1.01	191.2	236	1.11	38.9
11:15	231	1.03	227	236.3	1.02	194.4	237.1	1.12	40.8
11:30	230.8	1.03	228.7	237.6	1.03	196.7	237.8	1.14	40.9
11:45	234	1.06	235.9	238.7	1.03	197.4	235.5	1.13	39.1
12:00	233.3	1.04	231.8	237.1	1.04	197.9	237.7	1.13	42.5
12:15	2370	1.04	231.8	237	1.04	197	237	1.13	42.5
12:30	233.5	1.04	231.8	237.3	1.04	197	237.3	1.12	41.8
12:45	232.9	1.04	231.1	236.9	1.04	198	237.2	1.13	42.7
13:00	233.7	1.04	232.1	236.8	1.04	198.2	237.6	1.13	43.2
13:15	232.8	1.03	229.6	236.6	1.05	199.4	238.8	1.13	44.5
13:30	233.2	1.05	233	237.5	1.05	200.2	237.8	1.14	43.4
13:45	233.7	1.03	230.5	236.3	1.04	198.5	237.4	1.13	44
14:00	233.4	1.03	230	236	1.04	196.9	236.8	1.12	42.9

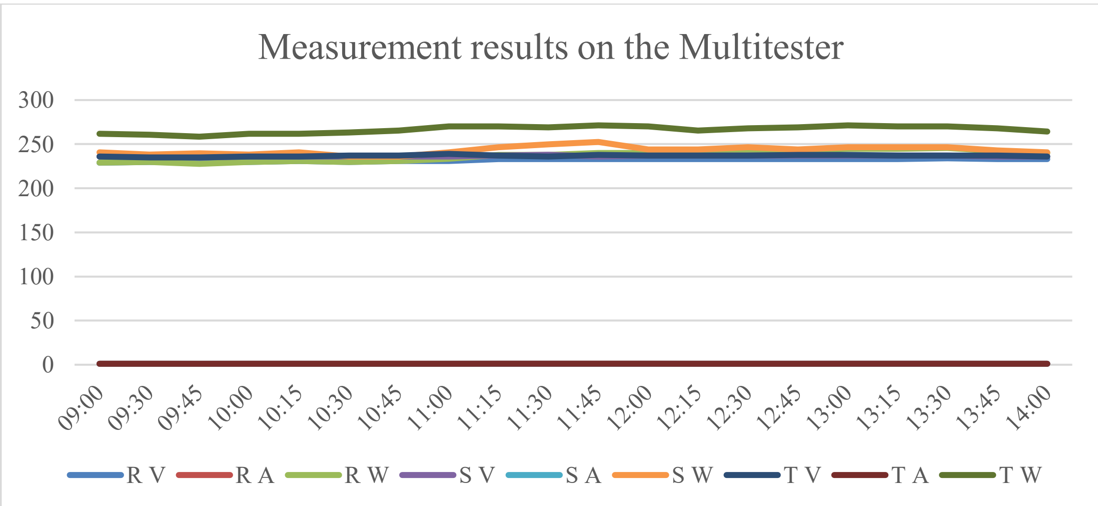


Figure 9. graph Measurement results on Multitester

Table 2. Measurement results on the Multitester

Time	R			S			T		
	V	A	W	V	A	W	V	A	W
9:00	229	1	229	236	1.02	240.72	236	1.11	261.96
9:30	230	1	230	236	1.01	238.36	235	1.11	260.85
9:45	230	0.99	227.7	235	1.02	239.7	235	1.1	258.5
10:00	230	1	230	236	1.01	238.36	236	1.11	261.96
10:15	231	1	231	236	1.02	240.72	236	1.11	261.96
10:30	230	1	230	236	1	236	237	1.11	263.07
10:45	231	1	231	236	1	236	237	1.12	265.44
11:00	231	1.01	233.31	236	1.02	240.72	239	1.13	270.07
11:15	233	1.02	237.66	237	1.04	246.48	237	1.14	270.18
11:30	233	1.02	237.66	238	1.05	249.9	236	1.14	269.04
11:45	233	1.03	239.99	236	1.07	252.52	238	1.14	271.32
12:00	233	1.03	239.99	237	1.03	244.11	237	1.14	270.18
12:15	233	1.03	239.99	237	1.03	244.11	237	1.12	265.44
12:30	233	1.04	242.32	237	1.04	246.48	237	1.13	267.81
12:45	233	1.04	242.32	237	1.03	244.11	238	1.13	268.94
13:00	233	1.05	244.65	237	1.04	246.48	238	1.14	271.32
13:15	233	1.05	244.65	237	1.04	246.48	237	1.14	270.18
13:30	234	1.05	245.7	237	1.04	246.48	237	1.14	270.18
13:45	233	1.04	242.32	236	1.03	243.08	237	1.13	267.81
14:00	233	1.03	239.99	236	1.02	240.72	236	1.12	264.32

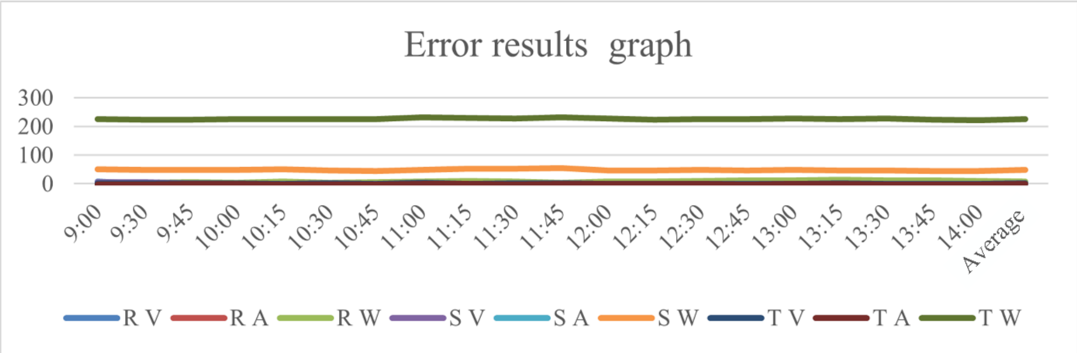


Figure 10. Error results graph

Table 3. Error Results Table

Time	R			S			T		
	V	A	W	V	A	W	V	A	W
9:00	7.4	0.3	2.6	5.6	0.02	50.72	1.2	0	225.96
9:30	0.5	0.03	4.6	5.5	0.01	48.06	1.6	0	223.85
9:45	0.4	0.02	5.3	1.3	0.01	48.9	1.5	0.01	224.1
10:00	0.6	0.02	4	0.7	0.01	48.76	1.1	0.01	225.46
10:15	1.3	0.02	7.8	0	0.01	51.12	0.3	0	225.5
10:30	0.5	0.02	4.8	0.9	0	46	2	0	225.97
10:45	1	0.02	6.8	0.5	0.01	44.2	0.4	0	226.34
11:00	0.1	0.01	7.31	0.3	0.01	49.52	3	0.02	231.17
11:15	2	0.01	10.66	0.7	0.02	52.08	0.1	0.02	229.38
11:30	2.2	0.01	8.96	0.4	0.02	53.2	1.8	0	228.14
11:45	1	0.03	4.09	2.7	0.04	55.12	2.5	0.01	232.22
12:00	0.3	0.01	8.19	0.1	0.01	46.21	0.7	0.01	227.68
12:15	4	0.01	8.19	0	0.01	47.11	0	0.01	222.94
12:30	0.5	0	10.52	0.3	0	49.48	0.3	0.01	226.01
12:45	0.1	0	11.22	0.1	0.01	46.11	0.8	0	226.24
13:00	0.7	0.01	12.55	0.2	0	48.28	0.4	0.01	228.12
13:15	0.2	0.02	15.05	0.4	0.01	47.08	1.8	0.01	225.68
13:30	0.8	0	12.7	0.5	0.01	46.28	0.8	0	226.78
13:45	0.7	0.01	11.82	0.3	0.01	44.58	0.4	0	223.81
14:00	0.4	0	9.99	0	0.02	43.82	0.8	0	221.42
Average	**1.235**	**0.0275**	**8.3575**	**1.025**	**0.012**	**48.3315**	**1.075**	**0.006**	**226.3385**

Figure 11. Notification in case of overload

4. CONCLUSION

This research successfully developed an IoT-based overload monitoring system for 3-phase electric motors using the PZEM-004T sensor and integration with the Telegram platform, which is able to monitor electrical parameters in real-time, send automatic notifications, and automatically cut off power when unsafe conditions are detected. The test results show that the voltage readings are quite accurate with an average difference of 1.235V (phase R), 1.025V (phase S), and 1.075V (phase T) compared to multimeter measurements, as well as relatively accurate current readings with an average error of 0.0275A (phase R), 0.012A (phase S), and 0.006A (phase T), although there are significant differences in power readings, especially in phase T with an average error reaching 226.3385W. For future research, it is recommended to integrate machine learning techniques for predictive analysis of motor failures, expand testing with different types of industrial loads (dynamic loads, impulsive loads, and non-linear loads), and develop redundancy systems to improve reliability. Although the system has successfully performed the monitoring and protection functions, there is still a need for recalibration to improve power measurement accuracy, further testing to ensure system reliability, as well as refinement on the power reading aspect which still shows significant imbalance, but overall this system makes an important contribution in improving the safety and efficiency of 3-phase electric motor monitoring in industry.

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