

System Monitoring and Protection System for Current and Voltage of Three-phase Induction Motors in Plastic Waste Shredders based on the Internet of Things (IoT)

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ABSTRACT

Induction motors are the primary components of plastic shredders and are vulnerable to damage caused by excessive current and unstable voltage. This study aims to design an IoT-based monitoring and protection system to enhance motor reliability. This system uses current and voltage sensors connected to a microcontroller (such as an ESP32) and includes a Wi-Fi module to transmit data to the cloud. Based on its implementation, this system is capable of monitoring motor conditions in real time, detecting current and voltage disturbances, and automatically disconnecting the power supply using a relay. The data can also be accessed through a user application, thereby facilitating remote monitoring.

Keywords

Induction motor, IoT, monitoring, protection and plastic shredder.

1. INTRODUCTION

Plastic waste shredders play a crucial role in the recycling process because they help reduce waste and enhance the usability of plastic materials [1]. In this system, the motor serves as the primary driver, operating continuously and handling a heavy workload. However, in practice, motors often encounter problems caused by overloading and poor power quality [2], [3]. If not addressed promptly, these conditions can lead to motor damage. The problem with this system is the lack of real-time monitoring, which prevents the operator from immediately knowing the motor's condition. Furthermore, motor damage can occur due to overloading, which causes the current to exceed the rated limit. Unstable voltage is also a significant factor that can disrupt motor performance and reduce its efficiency. To address these issues, an Internet of Things (IoT)-based system is needed to monitor current and voltage in real time [3], [4]. This system is also designed to provide automatic protection by cutting off the power supply when abnormal conditions occur and can send notifications to users remotely, enabling quick and accurate responses.

2. METHODOLOGY

2.1 Identification of Problems

Problems encountered in the operation of a three-phase induction motor system in a plastic waste shredder. The main problem identified is the lack of an adequate monitoring and

protection system, which prevents proper inspection of the motor's operating condition and increases the risk of damage. Motors that operate continuously under varying loads are susceptible to issues such as excessive current and unstable voltage [3], [5].

2.2 System monitoring issues

Problems in the monitoring system arise from limitations in obtaining real-time and continuous information about the motor's condition. The system is not yet able to display current and voltage data directly, making it difficult for operators to understand the motor's actual condition during operation. Monitoring is still performed manually and is not integrated with a digital system, resulting in inaccurate and unsustainable information [6]. Furthermore, the system still lacks the ability to automatically record data, resulting in insufficient historical data for further analysis. These limitations hinder the optimal assessment of the motor's performance. The lack of an IoT-based monitoring system prevents operators from performing remote monitoring, making supervision inefficient and highly dependent on the presence of on-site operators [4], [6].

2.3 Motor protection issues

Problems in the motor protection system arise from the absence of self-protection mechanisms that operate independently when abnormal conditions occur [3]. Motor systems are not equipped with mechanisms capable of quickly detecting and responding to disturbances such as excessive current and abnormal voltage [3], [5]. This allows the motor to continue operating under risky conditions, often resulting in a delayed response to disturbances. This delay can cause the motor to overheat, potentially damaging internal components such as the stator windings [3]. Therefore, an automatic protection system that operates quickly and is integrated with the monitoring system is required to maintain motor performance and safety [5].

2.4 Test Method

The testing method in this study was implemented to evaluate the performance of a previously designed Internet of Things (IoT)-based system for monitoring and protecting motor current and voltage pages. The testing process was carried out by observing the system's response to various motor operating conditions, both under normal operation and during fault conditions.

3. SYSTEM DESIGN

The system is designed by integrating the power circuit, control circuit, sensors, and an Internet of Things (IoT)-based communication module to ensure that the motor operates safely, efficiently, and can be monitored in real time. In the power circuit, a three-phase power supply (R, S, and T) is distributed through a Molded Case Circuit Breaker (MCCB), which serves as the primary protection against overcurrent and short circuits [3]. The power is then supplied to a contactor, which functions as an electromagnetic switch to connect or disconnect the motor from the power source. An overload relay is employed as an additional protection device to detect overload conditions that may damage the motor. Subsequently, an inverter or Variable Frequency Drive (VFD) is used to regulate the motor's speed and voltage before supplying it to the three-phase induction motor. In the control circuit, the system operates using a 220 VAC supply and is equipped with start, stop, and alarm push buttons for manual operation. In

addition, several input sensors are utilized, including an emergency stop, overload sensor, temperature sensor, and jam sensor, which function to detect abnormal operating conditions in the machine. All sensor data are transmitted to the ESP32 module, which acts as the IoT gateway. The ESP32 module serves as the central processing unit and connects the system to the internet via Wi-Fi. The processed data are then transmitted to a cloud platform for storage and analysis [4], [7]. Through a web-based or mobile dashboard, users can monitor key parameters such as current, voltage, temperature, and motor operating status in real time [4], [5], [7]. Furthermore, the system provides alarm notifications and remote control features (start/stop) to enhance operational safety and convenience [5], [7]. With this design, the system not only enables continuous monitoring but also provides automatic protection against electrical and mechanical disturbances. This contributes to extending the motor's lifespan and improving the operational efficiency of the plastic waste shredding machine.

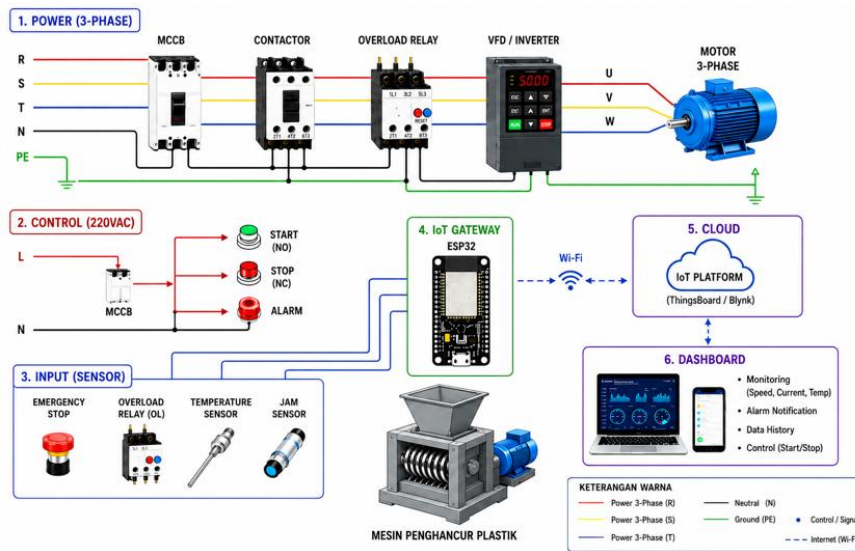


Fig 1: IoT-based motor control system for a plastic waste shredding machine

4. RESULTS AND DISCUSSION

This section presents the results of the system testing as well as an analysis of the performance of the monitoring and protection system in detecting both normal and abnormal motor conditions.

4.1 System Test Results

Testing was conducted to evaluate the performance of the current and voltage monitoring system, as well as the protection response under various motor operating conditions.

Table 1. Table current and voltage testing

No	Operating Conditions	Current (A)	Voltage (V)	Status Motor
1	Empty load	0	380	ON
2	Normal	3.2	380	ON
3	Overcurrent	3.4	400	OFF

The test results presented in Table 1 demonstrate the system's excellent ability to detect both normal and abnormal conditions. The system is capable of maintaining normal motor operation and providing automatic protective responses in the event of overloads and voltage drops.

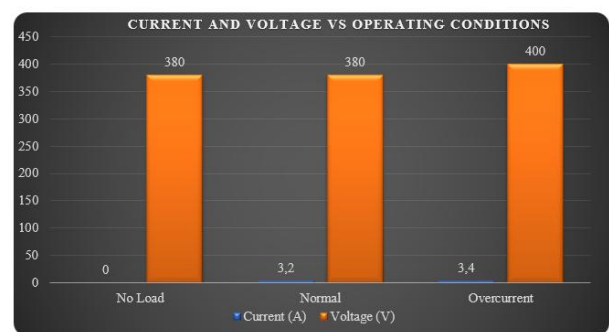


Fig 2: Current and voltage vs operating conditions

The graph shows that the current increases significantly with load variation, from 0 A to 3.4 A, indicating an increase in power demand. Meanwhile, the voltage remains relatively stable at 380 V under normal conditions but rises to 400 V under fault conditions. This confirms that the system is capable of effectively detecting electrical disturbances and providing an appropriate response.

4.2 Iot Monitoring Results

Based on IoT-based electric motor parameter monitoring obtained during system testing, the displayed data include motor voltage and current, which are monitored in real time and transmitted to the monitoring platform for analysis [4], [6], [7].

Table 2. IoT monitoring date

Time	Current (A)	Voltage (V)	IoT State	Notifications
08:00	0	380	Normal	There isn't any
08:30	3.2	380	Normal	The system is working fine
09:15	3.4	400	Warning	Motor is turned off

Based on IoT data, the motor operates normally at a current of 0–3.2 A and a voltage of 380 V (ON status). When an overcurrent condition occurs (3.4 A and 400 V), the system immediately switches the motor OFF. This demonstrates the system's ability to monitor and automatically protect the motor in real time.

4.3 System Performance

Based on the analysis conducted, the system demonstrated satisfactory performance in detecting changes in motor operating conditions. This system responded quickly to overload conditions, as indicated by a brief interruption of the electrical current via the relay. This indicates that the protection mechanism functioned effectively to prevent damage to the motor [3]. Furthermore, the IoT-integrated monitoring system enables real-time monitoring of current and voltage [4]. Data transmitted to the IoT platform can be easily accessed by users, making the monitoring process more efficient without requiring physical presence on site [4], [7]. No significant disturbances were detected in data communication or system response; therefore, it can be concluded that the system demonstrates reliable performance for application in monitoring and protecting motors in plastic waste shredding machines.

5. CONCLUSIONS

Based on the design and testing results, the IoT-based monitoring and protection system for a three-phase induction motor has been proven to operate effectively in improving

reliability and operational safety. The system is capable of monitoring current and voltage in real time and responding to abnormal conditions, such as overcurrent and unstable voltage, by automatically disconnecting the power supply.

Furthermore, the integration of IoT enables remote monitoring and rapid notification delivery, thereby enhancing supervision efficiency. Overall, the developed system is able to improve the performance, safety, and lifespan of the motor used in plastic waste shredding machines.

6. ACKNOWLEDGMENTS

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