ISSN (Online): 2455-3662
EPRA International Journal of Multidisciplinary Research (IJMR) - Peer Reviewed Journal
Volume: 11| Issue: 4| April 2025|| Journal DOI: 10.36713/epra2013 || SJIF Impact Factor 2025: 8.691 || ISI Value: 1.188

ARDUINO-BASED INTELLIGENT INDUCTION MOTOR PROTECTION SYSTEM

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Article DOI: https://doi.org/10.36713/epra21243
DOI No: 10.36713/epra21243

ABSTRACT

Induction motors are widely used in industries and households due to their durability and efficiency. However, they are prone to faults such as overcurrent, voltage fluctuations, and overheating, which can cause breakdowns and reduce performance. To address this, an Arduino-based motor protection system is proposed, offering real-time monitoring and automatic shutdown during abnormal conditions. The system integrates current (ACS712), voltage (ZMPT101B), and temperature (LM35) sensors with an Arduino Uno, which processes sensor data and triggers a relay to disconnect the motor if thresholds are exceeded. An LCD display provides real-time parameter updates, while a buzzer alerts users during faults. This low-cost, reliable solution enhances motor safety, prevents damage, and ensures efficient operation, making it ideal for small industries and educational applications. Future enhancements may include IoT connectivity and predictive maintenance using machine learning.

KEYWORDS: *Induction Motor, Arduino Uno, Overcurrent Protection, Overvoltage Protection, Temperature Monitoring, Motor Safety, Relay Module.*

INTRODUCTION

Induction motors are extensively utilized across industries due to their cost-effectiveness, durability, and high efficiency. However, their performance and operational lifespan can be severely compromised by electrical faults (such as overcurrent, voltage fluctuations, and phase imbalances) as well as environmental factors like overheating. Conventional protection mechanisms, including electromechanical relays and PLC-based systems, often suffer from limitations—either being insufficiently precise[4] or prohibitively expensive for small-scale applications[3].

To address these challenges, this research presents an affordable, scalable, and user-friendly Arduino-based protection system. The proposed solution employs sensors to continuously monitor critical parameters—current (via ACS712), voltage (using ZMPT101B), and temperature (with LM35)—and interfaces them with an Arduino microcontroller. Upon detecting any abnormality beyond predefined thresholds, the system automatically disconnects the motor via a relay, preventing potential damage. Additionally, real-time data is displayed on an LCD screen, while a buzzer provides immediate fault alerts.

This system offers a cost-efficient, reliable, and easily deployable alternative to traditional protection methods, making it particularly suitable for small industries, workshops, and educational demonstrations. Future enhancements could integrate wireless monitoring (IoT) and predictive analytics for smarter maintenance.

COMPONENTS USED

1. **Arduino Uno:** Acts as the central controller to process data from sensors and execute control commands.
2. **Current Sensor (ACS712):** Measures real-time current drawn by the motor.
3. **Voltage Sensor (ZMPT101B):** Monitors voltage levels supplied to the motor.
4. **Temperature Sensor (LM35):** Tracks motor temperature to prevent overheating.
5. **Relay Module (5V):** Disconnects the motor from the supply during fault conditions.
6. **LCD Display (16x2):** Displays real-time readings of current, voltage, and temperature.
7. **Induction Motor (1-HP):** The load whose parameters are monitored and protected.
8. **Breadboard & Connecting Wires**
9. **Power Supply (12V/5V regulated)**

METHODOLOGY

The protection system is built around the Arduino Uno board. Each sensor module is interfaced with analog pins of the Arduino. The methodology involves:

- **Voltage Monitoring:**The ZMPT101B voltage sensor[7] provides real-time voltage data to the Arduino, which processes the analog input using its built-in Analog-to-Digital Converter (ADC). The Arduino continuously monitors this digital voltage value and compares it against predefined safety limits, typically set within ±10% of the rated voltage. If the measured voltage exceeds these limits—indicating either overvoltage or undervoltage conditions—the system automatically triggers a shutdown. This immediate response helps protect the connected induction motor from potential

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damage due to abnormal voltage levels, ensuring safe and reliable operation under varying electrical conditions.

- **Current Monitoring:** The ACS712 current sensor [8] continuously monitors the current drawn by the induction motor and sends the data to the Arduino for processing. This analog signal is converted to a digital value, which the Arduino compares against a predefined safe current threshold set in the program. If the current exceeds this safe range, it may indicate an overload or a short-circuit condition. In response, the system promptly triggers a protective action, such as deactivating the relay to disconnect the motor from the power supply. This mechanism helps prevent potential damage to the motor and ensures safe operation during fault conditions.
- **Temperature Monitoring:** The LM35 temperature sensor [5] monitors the surface temperature of the induction motor and sends analog signals to the Arduino, which then converts them into digital values. The system continuously compares these readings with a predefined temperature threshold, typically set at 70°C. If the temperature exceeds this limit, it indicates a potential overheating condition, often caused by extended operation under heavy load or inadequate ventilation. When such a scenario is detected, the Arduino initiates a protective shutdown to prevent thermal damage to the motor, thereby enhancing operational safety and extending the motor's lifespan.
- **Control and Display:** When the Arduino detects any abnormal condition—such as overvoltage, overcurrent, or overheating—it immediately activates the relay module to disconnect the motor from the power supply, preventing potential damage[10]. Simultaneously, the system displays a detailed fault message on the LCD screen, indicating the type of fault (e.g., "Overcurrent Detected") along with the corresponding parameter value. This real-time feedback allows users to quickly identify and address the issue, ensuring safe and efficient operation of the induction motor. The integration of automatic control and clear visual alerts enhances the reliability and user-friendliness of the protection system.

CIRCUIT DIAGRAM

The circuit consists of sensors connected to Arduino's analog pins. The relay is connected to a digital pin to enable switching. The LCD is interfaced using I2C for easy communication. A clear diagram shows:

- ACS712 → A0
- ZMPT101B → A1
- LM35 → A2
- Relay → D8
- LCD (via I2C) → SDA/SCL

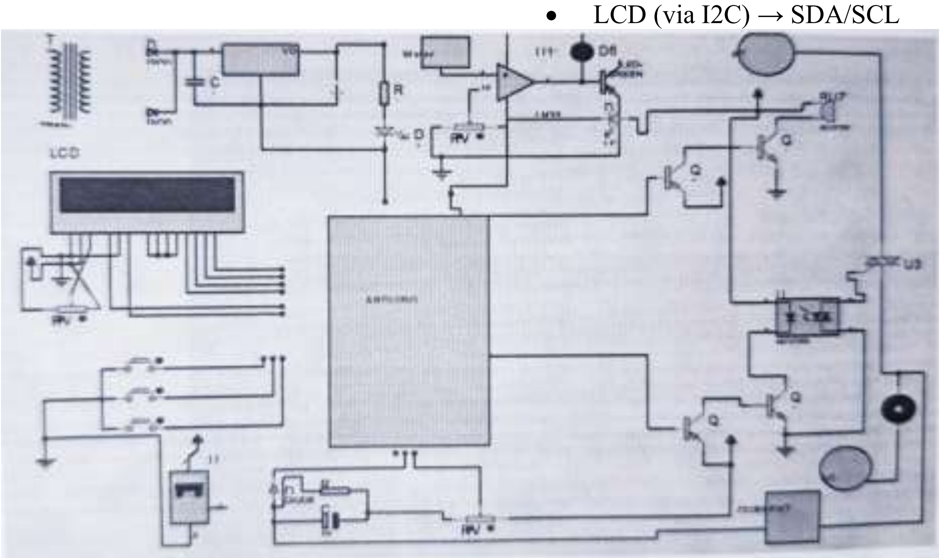

Figure 1. Circuit Diagram

WORKING

Under normal operating conditions, all sensors read within safe limits, and the relay remains closed to power the motor. When a fault is detected:

- **Overcurrent/Overvoltage:** The Arduino identifies the abnormal value and breaks the circuit via the relay.
- **Overheating:** If the temperature exceeds 70°C, the motor is turned off to cool down.
- The LCD displays the reason for shutdown, aiding in diagnosis and reset.

Resetting the system is done either manually or after conditions normalize.

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RESULTS AND OBSERVATIONS

Test Condition	Parameter Exceeded	Relay Status	Display Message
Normal Load	None	ON	Voltage: 220V, Temp: 40°C
Simulated Overload	Current > 5A	OFF	Fault: Overcurrent Detected
Voltage Surge	Voltage > 250V	OFF	Fault: Overvoltage Detected
High Temperature	Temp > 70°C	OFF	Fault: Overheat Detected

This system reliably prevents motor operation under unsafe conditions, reducing the risk of burnout or mechanical failure.

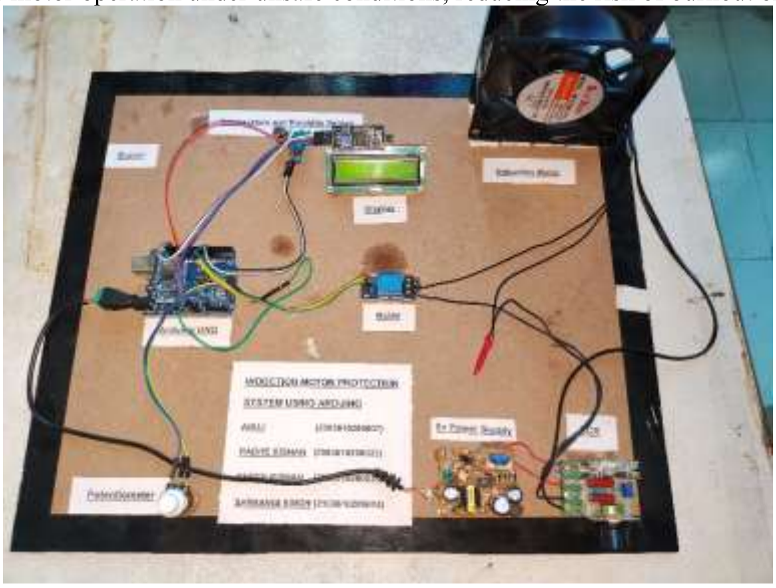

Figure 2. Project Model

ADVANTAGES

The Arduino-based induction motor protection system offers several key benefits that make it an attractive solution for both industrial and educational applications. First, it provides a low-cost, open-source alternative[16] to traditional protection systems, significantly reducing expenses while maintaining reliability. The system delivers real-time protection against multiple faults, including overcurrent, voltage fluctuations, and overheating, ensuring immediate response to prevent motor damage. Its modular and scalable design allows for easy customization[11], enabling users to adjust protection thresholds or expand functionality for different motor specifications. Additionally, the system minimizes maintenance requirements and operational downtime[12] by proactively detecting and mitigating faults before they escalate. An integrated LCD display provides clear visual alerts, enhancing user awareness by displaying real-time parameters and fault diagnostics, simplifying troubleshooting and system reset procedures. These advantages make the system an efficient, user-friendly, and cost-effective solution for motor protection.

CONCLUSION

The Arduino-based Induction Motor Protection System represents a significant advancement in affordable motor safety solutions[1]. By leveraging cost-effective sensor technology [9]and microcontroller-based intelligence, the system provides comprehensive[3] protection against critical faults including overcurrent, voltage irregularities, and thermal overload. The modular architecture offers exceptional flexibility, enabling straightforward customization for various motor specifications and the potential for expanded monitoring capabilities.

This solution not only addresses immediate [11] protection needs but also establishes a foundation for future enhancements. With additional development, the system can evolve into a smart monitoring platform through IoT integration[6], enabling features such as remote diagnostics, cloud-based data logging, and predictive maintenance algorithms. The combination of robust protection[12], economic viability, and scalability makes this system particularly valuable for small-to-medium industrial applications, educational environments, and developing markets where cost-effective automation solutions are essential.

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