



IJRASET

International Journal For Research in
Applied Science and Engineering Technology



INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 **Issue:** IV **Month of publication:** April 2025

DOI: <https://doi.org/10.22214/ijraset.2025.68389>

www.ijraset.com

Call:  08813907089

E-mail ID: ijraset@gmail.com

Design and Implementation of a Smart Induction Motor Control and Protection System for Low-Power Applications

Associate Prof. Dr. B.N. Shinde¹, Harish Deore², Sumeet Chavhan³, Dhiraj Bachhav E⁴

E & TC Department, MVPS's KBTCOE Nashik, India

Abstract: Induction motors play a critical role in industrial, commercial, and residential applications due to their robust design, reliability, and cost-effectiveness. However, these motors are susceptible to various electrical and mechanical issues such as overcurrent, under-/over-voltage, and overheating, which can lead to insulation failure and reduced lifespan. This paper presents a low-cost, compact induction motor control and protection system that integrates multiple sensors—including current, temperature, vibration, and voltage sensors—with an ATmega328 microcontroller for real-time monitoring. The system is designed to detect abnormal operating conditions promptly and initiate protective actions to disconnect the motor, thereby mitigating damage and enhancing longevity. Additionally, the inclusion of a Bluetooth module enables remote monitoring and control, making the solution practical for environments with limited infrastructure. An intuitive local interface featuring a 16×2 LCD display further facilitates immediate feedback and operation. Although the current implementation relies on rule-based logic, the system is scalable and serves as a foundation for future predictive maintenance integration using machine learning and deep learning techniques.

Index Terms: Induction Motor, Protection System, Overcurrent Protection, Voltage Monitoring, Bluetooth Control, Sensor Integration, Motor Safety, Predictive Maintenance

I. INTRODUCTION

In industries and everyday applications, induction motors are the backbone of countless systems, prized for their durability, efficiency, and affordability. These motors work by generating a magnetic field in the stator, which induces current in the rotor to produce rotational force. This straightforward mechanism—paired with their low production costs and long service life—has cemented single-phase and three-phase induction motors as irreplaceable in factories, homes, and automated systems.

Yet, even these robust machines face risks. Voltage fluctuations (both under- and over-voltage) and overheating can degrade insulation and shorten a motor's lifespan. Overvoltage strains components and accelerates wear, while under-voltage

This research was conducted at MVPS's KBT College of Engineering, Nashik. prevents smooth startups, leading to inefficiencies. Compounding this, small-scale industries often lack access to stable power supplies or advanced protection systems due to cost barriers. This project introduces a compact, cost-effective system to safeguard induction motors. By combining current, temperature, vibration, and voltage sensors with an ATmega328 microcontroller, the system monitors critical metrics in real time. If unsafe conditions arise—like overheating or voltage spikes—it automatically shuts down the motor to prevent damage. A Bluetooth module enables wireless control and remote monitoring via smartphones, bypassing the need for complex infrastructure.

The system prioritizes ease of use, featuring a 16×2 LCD for instant status updates and simple calibration. While it currently uses rule-based logic to detect faults, the design allows future upgrades for predictive maintenance using machine learning or deep learning, ensuring adaptability as technology evolves. In essence, this control and protection system enhances motor safety, reduces downtime, and extends equipment life across industrial and small-scale settings—all without breaking the bank.

A. Problem Statement

Induction motors are central to industrial and domestic operations but remain vulnerable to voltage irregularities, overheating, overcurrent, and phase imbalances. These issues degrade insulation and cause failures. Traditional protection methods lack real-time monitoring and automated responses, leaving smaller businesses reliant on outdated practices that fail to prevent costly breakdowns.

B. Objectives

- 1) Real-Time Monitoring: Track voltage, current, temperature, and vibration continuously for instant feedback.
- 2) Automated Protection: Disconnect or adjust the motor automatically during unsafe conditions.
- 3) Remote Control: Enable wireless ON/OFF control, speed adjustments, and data access via Bluetooth.
- 4) Local Status Display: Provide real-time alerts and diagnostics through an LCD screen.
- 5) Efficiency Optimization: Improve energy use by analyzing performance trends over time.

II. MOTIVATION

Induction motors are the heartbeat of industrial and household systems, powering essential equipment even under demanding conditions. Threats like overcurrent, voltage fluctuations, overheating, and phase imbalances can rapidly degrade motor performance, slash efficiency, and trigger expensive unplanned shutdowns. Conventional protection systems fall short by lacking real-time insights or automated safeguards, leaving many facilities stuck with outdated, “wait-and-fix” approaches.

Our work is driven by the urgent need for an affordable, proactive solution that monitors motors around the clock and acts instantly to prevent damage. By merging sensors (for current, voltage, temperature, and vibration) with an ATmega328 microcontroller and adding Bluetooth-enabled remote control, the system boosts motor reliability while cutting repair costs. Beyond immediate protection, it opens the door to future predictive maintenance by gathering actionable performance data.

III. RELATED WORK

Existing research on motor control, fault detection, and optimization has informed our project’s design and goals. Key contributions include:

A 2020 review by Journal, I. maps the progression of traction motor technology, showcasing how motor current signature analysis pinpoints faults like rotor/stator defects, bearing wear, and vibration irregularities. The study underscores AI’s rising role in refining fault detection, offering a roadmap for next-gen diagnostic tools.

Bonet-Jara et al. (2021) dissect methods for fine-tuning weighting factors in finite control set PWM techniques. Their work separates approaches into offline and online categories, spotlighting adaptive online strategies that dynamically adjust settings for optimal motor control. This analysis helps engineers choose the most effective methods for specific applications.

Jannati et al. (2017) explore variable frequency drives (VFDs) for induction motor speed control, detailing how VFDs enable flexible, efficient operation under varying loads. Their research reinforces VFDs as a cornerstone of modern motor control systems.

Ouanjli et al. (2019) tackle sensorless speed estimation in induction motors, linking these techniques to fault diagnosis.

By evaluating commercial diagnostic tools and real-world case studies, they identify gaps in current sensorless methods and chart paths for future innovation.

Hannan et al. (2018) emphasize the need for smarter control strategies for single-phase induction motors (SPIMs) in homes and businesses. Their review of variable speed control methods highlights ways to balance energy efficiency with performance.

Subasri et al. (2020) analyze upgrades to traditional direct torque control (DTC) for induction machines. They compare modern strategies that improve torque/flux regulation while simplifying algorithms and reducing losses, offering a clear view of DTC’s evolving landscape.

Talla et al. (2018) provide a sweeping review of control and optimization tactics for induction motor drives, covering scalar/vector control, V/f control, and field-oriented methods. Their work serves as a guide for advancing motor drive technology.

Sobhi et al. (2023) focus on condition monitoring for small industrial motors, demonstrating how machine learning—both shallow and deep models—can detect faults across multiple motors. Their ongoing project highlights the shift toward AI-driven diagnostics.

Finally, Gudiño-Ochoa et al. (2023) investigate how AC drives interact with induction motors, particularly their role in generating interharmonics. Using time-frequency analysis, they reveal how different AC drives influence harmonic behavior, informing safer motor-drive integration.

IV. SYSTEM ARCHITECTURE

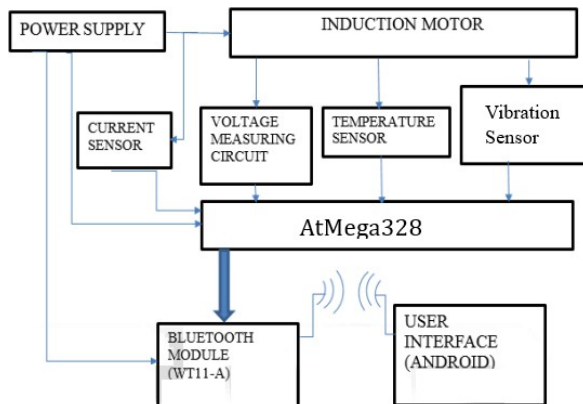


Fig.1.SystemArchitecture

The System (Fig. 1) safeguards single-phase induction motors by merging real-time sensor monitoring with Bluetooth control. Unlike medical systems that process text or images, this setup focuses on four dedicated sensor “streams,” each tracking a key motor parameter: current, voltage, temperature, and vibration.

A. Sensor Data Paths:

- 1) **Current Sensor Path:** Tracks live current flow to catch overloading or insufficient draw before it harms the motor.
- 2) **Voltage Sensor Path:** Watches for voltage dips or spikes that strain the motor or stall startups.
- 3) **Temperature Sensor Path:** Tracks the motor’s operating temperature; any reading exceeding the threshold (e.g., 80°C) triggers immediate protective actions.
- 4) **Vibration Sensor Path:** Detects abnormal mechanical vibrations that may signal bearing wear, misalignment, or other mechanical faults.

B. Microcontroller Processing:

All sensor feeds funnel into the ATmega328 microcontroller. Like filtering noise from a medical dataset, the microcontroller cleans up sensor signals (filtering/debouncing) and checks them against safety thresholds. If danger zones are breached, it cuts power via a relay—think of it as an emergency brake for motors.

C. Wireless Communication Path:

Instead of cloud dependency, a Bluetooth module handles wireless comms. The microcontroller bundles sensor data and beams it to an Android app, letting users monitor stats or trigger shutdowns remotely. This keeps things cheap and offline-friendly—no internet needed.

D. Local Display and User Feedback:

While medical systems might show diagnostic images online, ours uses a no-nonsense 16×2 LCD. It flashes live voltage, temperature, vibration, and current readings so workers can act fast without pulling out a phone.

E. Protective Actions and Data Logging:

When sensors scream “trouble,” the microcontroller kills the motor’s power and logs the incident. These records help tweak safety thresholds later. Right now, it’s all rule-based, but the data stash could train AI models for smarter, predictive upkeep down the line.

F. How Our Work Differs From Previous Approaches

- 1) **360° Health Check:** Rather than focusing on a single parameter (like current or temperature), our architecture integrates four distinct sensors, offering a more holistic view of the motor’s health.
- 2) **Local and Wireless Control:** Instead of a web-based or cloud-driven system, we employ a Bluetooth module for cost-effective, offline-capable monitoring and control. This design is well-suited for environments with limited or unreliable internet connectivity.

- 3) *Future-Ready Design*: Though our current solution uses threshold-based logic, the logged sensor data can be leveraged in the future for machine learning or deep learning models, enabling predictive fault detection and advanced diagnostics.
- 4) *User-Centric Interface*: A 16×2 LCD display offers immediate, on-site visual feedback, while the Android application provides remote oversight. This dual-interface approach accommodates both local operators and off-site maintenance personnel, improving safety and reducing downtime.

V. CONTROL AND PROTECTION ALGORITHM

The ATmega328 microcontroller forms the computational core of the system, analyzing real-time sensor data to protect induction motors from electrical, thermal, and mechanical failures. The algorithm operates in two integrated phases: Sensor Data Processing (calibrating inputs) and Decision- Making & Actuation (enforcing protective protocols), with thresholds validated through laboratory testing.

A. Sensor Data Processing

1) Current Monitoring with ACS712:

- **Operational Mechanism**: The ACS712 Hall Effect sensor generates a voltage proportional to motor current. For the 5A model, sensitivity is 185mV/A. At 0A, it outputs 2.5V. For example:

$$I = \frac{2.9V - 2.5V}{0.185V/A} \approx 2.16A.$$

- **Role in Protection**: Triggers shutdown within milliseconds if current exceeds 2 A, preventing winding insulation failure.

2) Voltage Monitoring via Resistive Divider:

- **Operational Mechanism**: A 30 kΩ + 7.5 kΩ resistor network scales supply voltage to the microcontroller's 5 V ADC. For 230 V AC:

$$V_{scaled} = 230V \times \frac{7.5}{37.5} = 46V.$$

- **Role in Protection**: Flags deviations $\pm 10\%$ (e.g., $\pm 207V$ or $\pm 253V$) to prevent stator core saturation.

3) Temperature Sensing with LM35:

- **Operational Mechanism**: Linear 10 mV/°C output (e.g., 800 mV at 80°C). Temperature calculated as:

$$T(^{\circ}C) = \frac{V_{out}}{0.01}$$

- **Role in Protection**: Initiates shutdown at 80°C to prevent bearing lubrication breakdown.

4) Vibration Detection with SW-420:

- **Operational Mechanism**: Digital HIGH output for vibrations exceeding a potentiometer-adjusted threshold (calibrated to ignore routine motor hum).
- **Role in Protection**: Sustained HIGH signals (≥ 5 seconds) indicate bearing wear/misalignment, enabling preemptive maintenance.

B. Decision-Making and Actuation

1) Threshold Comparison & Fault Prioritization:

- **Operational Workflow**:
 - Current: $\geq 2A$ → Overcurrent
 - Voltage: $\pm 10\%$ deviation → Anomaly
 - Temperature: $\geq 80^{\circ}C$ → Overheat
 - Vibration: Sustained HIGH → Mechanical fault

- Fault Hierarchy: Overheating; Overcurrent; Voltage anomalies; Vibration (validated via FMEA).
- 2) *Protective Action Execution:*
 - Emergency Protocol: 5VSPDT relay disconnects power within 10 ms (e.g., 8 ms response limits energy dissipation to 5 J in windings).
- 3) *Communication & Data Logging:*
 - Local Feedback: 16×2 LCD displays real-time parameters:
 - Line 1: Current—Voltage
 - Line 2: Temperature—Vibration Status
 - Wireless Transmission: HC-05 Bluetooth module (9600 baud) relays data to Android app for threshold customization.
 - Data Storage: CSV logs with timestamps enable machine learning-driven predictive maintenance.
- 4) *Post-Fault Recovery:*
 - Recovery Protocol: Resumes operation only when:
 - Temperature; 70°C (prevents rapid cycling)
 - Voltage stable (207–253 V) for ≥30 seconds
 - Vibration returns to LOW for ≥1 minute
 - Manual restart via app or auto-restart after 5-minute delay.

VI. CONCLUSION

Our induction motor control and protection system effectively integrates multi-sensor monitoring (current, voltage, temperature, vibration) with real-time processing via the ATmega328 microcontroller and wireless communication to safeguard motor operation. By employing precise threshold-based fault detection and millisecond-level protective actions, the system enhances reliability, reduces downtime, and lays a foundation for predictive maintenance through event logging. The dual-interface design—combining a 16×2 LCD for local alerts and Bluetooth for remote control—ensures adaptability across industrial settings. This cost-effective, scalable solution addresses critical protection challenges, ensuring immediate safety and long-term efficiency gains for motor-dependent applications.

REFERENCES

- [1] C.B. Jacobina, M.B. de Rossiter Correa, E.C. da Silva, and A.M. N. Lima, "Induction Motor Drive System for Low-Power Applications," *IEEE Trans. Ind. Appl.*, vol. 35, no. 1, pp. 52–61, Jan. 1999.
- [2] M. Mamdouh, M. A. Abido, and Z. Hamouz, "Weighting Factor Selection Techniques for Predictive Torque Control of Induction Motor Drives: A Comparison Study," *Arabian J. Sci. Eng.*, vol. 43, no. 2, pp. 433–445, Feb. 2018, doi:10.1007/s13369-017-2842-2.
- [3] J. Bonet-Jara, A. Quijano-Lopez, D. Morinigo-Sotelo, and J. Pons-Llinares, "Sensorless Speed Estimation for the Diagnosis of Induction Motors via MCSA: Review and Commercial Devices Analysis," *Sensors*, vol. 21, no. 15, p. 5037, Jul. 2021, doi:10.3390/s21155037.
- [4] M. Jannati, S. A. Anbaran, S. H. Asgari, W. Y. Goh, A. Monadi, M. J. Aziz, and N. R. N. Idris, "A Review on Variable Speed Control Techniques for Efficient Control of Single-Phase Induction Motors: Evolution, Classification, and Comparison," *Renew. Sust. Energy Rev.*, vol. 75, pp. 1306–1319, Aug. 2017, doi:10.1016/j.rser.2016.11.115.
- [5] N. El Ouanjli, A. Derouich, A. El Ghzizal, S. Motahhir, A. Chebabhi, Y. El Mourabit, and M. Taoussi, "Modern Improvement Techniques of Direct Torque Control for Induction Motor Drives – A Review," *Prot. Control Mod. Power Syst.*, vol. 4, no. 1, Dec. 2019, doi:10.1186/s41601-019-0125-5.
- [6] M. A. Hannan, J. A. Ali, A. Mohamed, and A. Hussain, "Optimization Techniques to Enhance the Performance of Induction Motor Drives: A Review," *Renew. Sust. Energy Rev.*, vol. 81, pp. 1611–1626, Jan. 2018, doi:10.1016/j.rser.2017.05.240.
- [7] J. Talla, V. Q. Leu, V. Smidl, and Z. Peroutka, "Adaptive Speed Control of Induction Motor Drive with Inaccurate Model," *IEEE Trans. Ind. Electron.*, vol. 65, no. 11, pp. 8532–8542, Nov. 2018, doi:10.1109/TIE.2018.2811362.
- [8] S. Sobhi, M. Reshadi, N. Zarft, A. Terheide, and S. Dick, "Condition Monitoring and Fault Detection in Small Induction Motors Using Machine Learning Algorithms," *Information*, vol. 14, no. 6, p. 329, Jun. 2023, doi:10.3390/info14060329.
- [9] A. Gudin'o-Ochoa, J. Jalomo-Cuevas, J. E. Molinar-Solis, and R. Ochoa-Ornelas, "Analysis of Interharmonics Generation in Induction Motors Driven by Variable Frequency Drives and AC Choppers," *Energies*, vol. 16, no. 14, p. 5538, Jul. 2023, doi:10.3390/en16145538.
- [10] Y. Chang, H. Yan, W. Huang, R. Quan, and Y. Zhang, "A Novel Starting Method with Reactive Power Compensation for Induction Motors," *IET Power Electron.*, vol. 16, no. 3, pp. 402–412, Mar. 2023, doi:10.1049/pel2.12410.
- [11] G. K. Dubey, *Fundamentals of Electrical Drives*, 2nd ed., Narosa Publishing House, 2012.
- [12] M. H. Rashid, *Power Electronics Circuits, Devices & Applications*, PHI, New Delhi, 2001.
- [13] R. A. Bhave, M. S. Gogate, A. A. Maity, and P. D. Shivthare, "Wireless Automation of an Electrical Drive Using Bluetooth," *IJESRT*, vol. 2, no. 11, pp. 3291–3294, Nov. 2013.
- [14] R. Parekh, "AC Induction Motor Fundamentals," *Microchip Technology Inc.*, 2003.



10.22214/IJRASET



45.98



IMPACT FACTOR:
7.129



IMPACT FACTOR:
7.429



INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Call : 08813907089  (24*7 Support on Whatsapp)