IoT Based Speed Control and Monitoring of Induction Motor

Jayesh Kavekar
E&TC Engineering MVPS's KBTCOE
Nashik, India

Yogita Kavade
E&TC Engineering MVPS's KBTCOE
Nashik, India

Minakshi Kasav
E&TC Engineering MVPS's KBTCOE
Nashik, India

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Abstract— *The Internet of Things (IoT) is taking great hold in today's technology since it facilitates comfortable and remote monitoring of machines using sensors. On the other hand. Single Phase Induction motors are most widely used in industry as well as home applications. Monitoring and controlling it is a very crucial task. This project is about monitoring several parameters such as the current, voltage, temperature, and speed of an induction motor, and controlling its speed by IOT, the faults are sensed using sensors and are stored in the cloud thereby enabling one to monitor the machine with reduced manual intervention. If the engine has a faulty state (current), the user will be notified of this issue via the mobile application Speed sensors are required for the control of induction motors and temperature sensors are required to find excessive thermal stress. These sensors reduce the sturdiness of the system and make it expensive. Therefore, a drive system without sensors is required.*

Key words*: IOT, *Atmega328, Induction Motor, Remote Monitoring, Sensor.

I. INTRODUCTION

General purpose of motors are increasing widely in our surrounding from household equipment's to machine tools in industrial applications. It is a necessary and indispensable source of power in many industries. In many applications the speed control plays a vital role which can be done using many control strategies The purpose speed controller of a motor is to take signal representing the demanded speed and to drive a motor at that speed. Generally speed control of the motor can be can be done by varying the motor parameters of the induction motor such as current, voltage, frequency etc. this can be achieved by different methods such as field control method, armature control method etc. In this project speed control is done by ZCD technique and the parameters are monitored and displayed in LCD by Atmega328 microcontroller and shared to mobile using IOT through NodeMCU Wi-Fi module which makes the whole system flexible and user friendly. With the help of IOT through NodeMCU the required speed is given as input to ZCD through Atmega328 microcontroller thus varying the speed of induction motor. Present industry is increasingly shifting towards automation. Two principle components of today's industrial automations are programmable controllers and robots. In order to aid the tedious work and to serve the mankind, today there is a general tendency to develop an intelligent operation.

A. Problem Statement

Induction motors are integral to various industrial processes, yet traditional speed control methods are often limited by fixed operations and manual adjustments, leading to inefficiencies, increased energy consumption, and higher operational costs. The lack of real-time monitoring makes it challenging to adapt motor performance to varying load conditions and operational requirements, resulting in suboptimal performance and potential equipment failures. The challenge is to develop an IoT-based speed control system that enables control of induction motors.

B. Objectives

- The primary objective of this project is to design and implement an IoT-enabled control mechanism that enhances the efficiency, reliability, and flexibility of induction motor operations.
- Develop a system that enables continuous monitoring of induction motor parameters, such as speed, and temperature, using IoT sensors.
- Implement an IoT-based control mechanism that allows for real-time adjustments of motor speed based on user-defined parameters and load conditions.
- Design the system to be scalable, allowing for the addition of more motors or sensors as operational needs evolve.

II. Motivation

As global energy prices continue to rise and sustainability becomes a core industrial priority, industries are increasingly driven to adopt innovative technologies that reduce energy consumption and operational costs. One of the most effective strategies to achieve this is through the implementation of IoT-based speed control systems for induction motors. These systems offer intelligent, real-time adjustments to motor speed based on load demand, significantly improving energy efficiency and contributing to substantial cost savings over time. Furthermore, the growing emphasis on smart manufacturing and the principles of Industry 4.0 have created a pressing need for more advanced, automated control systems. Integrating IoT technologies into motor control infrastructures aligns seamlessly with these modern industrial trends, enabling greater system intelligence, adaptability, and responsiveness. IoT solutions provide the added advantage of remote monitoring and control, allowing operators, technicians, and plant managers to access real-time motor performance data from any location. This not only improves operational flexibility but also facilitates faster response to anomalies or shifting production requirements, minimizing downtime and enhancing overall process efficiency. Ultimately, the transition to IoT-enabled motor control systems represents a forward-thinking approach that combines technological advancement with practical industrial benefits, paving the way for smarter, greener, and more cost-effective operations.

III. Related Work

Numerous studies have focused on the control and monitoring of induction motors using embedded systems and IoT technologies. Traditional methods of speed control often involved manual intervention and lacked real-time monitoring capabilities. With the advancement of microcontrollers and IoT platforms, modern systems now provide automation, precision, and remote accessibility.

Researchers have explored TRIAC-based phase angle control for regulating the speed of single-phase induction motors. The firing angle of the TRIAC is adjusted to control the effective voltage supplied to the motor, thereby controlling its speed. Accurate triggering of the TRIAC is achieved using Zero-Crossing Detection (ZCD) circuits, which synchronize the switching operation with the AC mains.

Microcontrollers such as ATmega328 have been widely used for implementing the firing angle control algorithm due to their timing accuracy. Additionally, NodeMCU (ESP8266) is increasingly used for IoT applications because of its built-in Wi-Fi capabilities, allowing for real-time data transmission and remote control via cloud platforms.

Several projects have integrated voltage and current sensors (e.g., ZMPT101B and ACS712) to monitor the operational status and performance of induction motors. These sensors help in detecting anomalies, preventing damage, and improving energy efficiency. The collected data can be transmitted wirelessly to IoT dashboards for live monitoring and data logging.

This project builds upon these existing technologies by integrating voltage and current sensors, a ZCD circuit, a TRIAC-based firing control system, ATmega328 for control logic, and NodeMCU for IoT connectivity. The system enables efficient speed control and real-time monitoring of a single-phase AC induction motor, demonstrating an effective combination of power electronics and IoT.

IV. System Architecture

The proposed system is designed to control and monitor the speed of a single-phase AC induction motor using TRIAC-based phase angle control, with real-time data monitoring through an IoT platform. The architecture integrates both hardware and software components to enable automated, accurate, and remote operation.

The system is composed of the following main components:

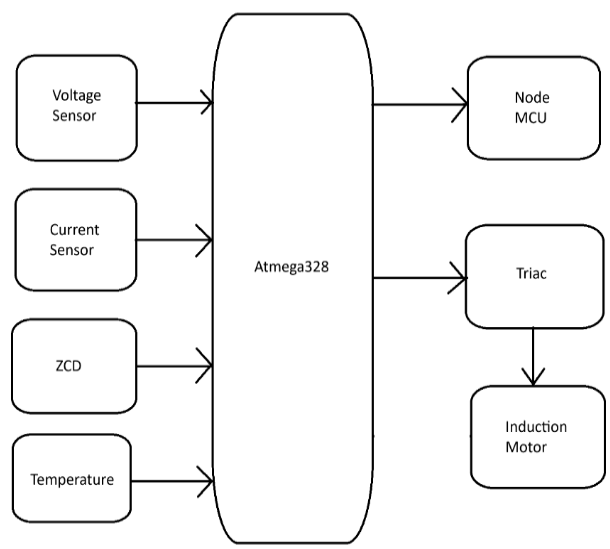

Fig. 1. System Architecture

System Flow

1. AC Mains Input → ZCD Circuit:
   - The ZCD detects the point at which the AC signal crosses zero and sends a timing pulse to the ATmega328.
2. Microcontroller (ATmega328):
   - Uses ZCD pulse to determine the correct delay for TRIAC firing.
   - Adjusts firing angle based on input from IoT platform.
   - Reads voltage, current, and temperature sensor data.
3. TRIAC Circuit (MOC3021 + BT136):
   - Triggered by the ATmega328 after a calculated delay.
   - Regulates power to the motor by adjusting the conduction time of AC waveform.
4. Sensor Feedback → NodeMCU:
   - ATmega328 sends sensor data to NodeMCU via serial communication.
   - NodeMCU uploads data to an IoT cloud platform and can also receive user commands.
5. IoT Cloud Platform (Blynk/ThingSpeak):
   - Displays real-time parameters.
   - Allows remote users to adjust motor speed through a mobile app or web interface.
6. Output to Motor:
   - The motor operates with variable speed based on the controlled AC power input.

1. Communication Architecture

- ATmega328 ↔ NodeMCU (UART): Exchange of sensor data and control instructions.
- NodeMCU ↔ Cloud (Wi-Fi): Remote monitoring and control.
- User ↔ Mobile/Web App: Live control and data viewing through the cloud.

2. Safety and Power Supply

- Opto-Isolator (MOC3021): Ensures electrical isolation between control and power circuits.
- 7805 Regulator: Converts unregulated DC to a stable 5V for microcontroller and sensors.

3. User Interface

- LCD Module (16x2): Displays motor voltage, supply voltage, current, and temperature.
- Mobile App (e.g., Blynk): Allows remote speed control and live data monitoring.

V. IMPLEMENTATION STRATEGY AND SECURITY IMPLEMENTATION

The implementation of the IoT-based speed control and monitoring system for an induction motor was carried out using a modular and structured approach. The hardware was developed first by constructing the zero-crossing detector (ZCD) circuit to detect the exact point where the AC waveform crosses zero, which is essential for accurate phase angle control. The ATmega328 microcontroller was programmed to calculate the appropriate firing delay after each zero crossing and to trigger the TRIAC through an opto-isolator (MOC3021), which provides electrical isolation between the microcontroller and the high-voltage AC circuit. The TRIAC (BT136) was used to control the power delivered to the motor, enabling variable speed operation.

Two voltage sensors were used in this project—one to measure the input supply voltage and another to monitor the voltage across the motor after phase control. Additionally, a current sensor (ACS712) and a temperature sensor (DS18B20) were integrated to monitor the motor's electrical load and operating temperature in real time. All sensor readings were collected by the ATmega328 and transmitted to the NodeMCU (ESP8266) using UART serial communication. The NodeMCU was programmed to connect to a Wi-Fi network and communicate with a cloud-based IoT platform such as Blynk or ThingSpeak. This enabled remote monitoring of motor parameters and allowed users to control the motor speed through a mobile application.

The software for both the microcontroller and the NodeMCU was developed using the Arduino IDE. The ATmega328 was programmed in embedded C to manage TRIAC firing and sensor interfacing, while the NodeMCU handled network communication and cloud integration. A 16x2 LCD display was added to provide local feedback by displaying real-time values of voltage, current, and temperature. After successful integration, the system was tested and calibrated to ensure accuracy and responsiveness under various load conditions.

A. *Methodology:*

1. The methodology adopted for this project involves the combination of phase angle control, sensor-based monitoring, and IoT communication to achieve efficient and remote speed control of a single-phase induction motor. Initially, a Zero Crossing Detector (ZCD) circuit was designed to identify the exact points where the AC waveform crosses zero volts. These points are essential for synchronized TRIAC triggering, which is used to vary the phase angle and control the amount of power delivered to the motor. The ATmega328 microcontroller receives the zero-crossing signal and calculates the firing delay based on user input, which effectively controls the motor's speed.
2. To monitor the system's performance, various sensors were integrated. Two voltage sensors (ZMPT101B) were used—one to measure the supply voltage and another to measure the voltage reaching the motor after control. A current sensor (ACS712) was used to measure the motor's load current, and a temperature sensor (DS18B20) monitored the motor's surface temperature to prevent overheating. All sensor data were collected by the ATmega328 and sent to the NodeMCU (ESP8266) via serial communication.
3. The NodeMCU acts as a bridge between the local system and the internet. It connects to a cloud platform (such as Blynk or ThingSpeak) using Wi-Fi, allowing real-time data to be uploaded and displayed on a mobile application. Users can monitor the motor's voltage, current, and temperature, and can also control the speed remotely using the app interface. The system is powered using a regulated DC supply derived from a 7805 voltage regulator, and an LCD display is used to show live readings locally.
4. The entire system was built, tested, and calibrated in stages, starting with individual component testing and ending with full integration. Special attention was given to electrical isolation, protection circuits, and software logic to ensure the system is reliable, safe, and responsive. This structured methodology allowed successful implementation of a smart, IoT-based induction motor control system.

How Our Work Differs from Previous Approaches:

- IoT Integration for Remote Control
  – Unlike earlier systems that relied on manual speed adjustment, our system enables remote speed control through a mobile application using the NodeMCU (ESP8266) and Wi-Fi connectivity.
- Dual Voltage Monitoring
  – We use two voltage sensors to monitor both the input supply voltage and the controlled motor-side voltage, which offers better visibility into power quality and TRIAC performance—an improvement over single-sensor systems.
- Comprehensive Parameter Monitoring
  – In addition to voltage, our project monitors current and temperature, giving users a complete overview of motor health—previous designs often neglected these parameters.
- TRIAC Control with Zero-Crossing Synchronization
  – Our system uses a zero-crossing detector (ZCD) to ensure phase-aligned TRIAC triggering, achieving smoother and more accurate speed control compared to crude firing circuits used in earlier methods.
- Bidirectional Communication
  – Unlike many projects that only display data on an LCD, our design supports bidirectional communication, allowing users to both monitor and control the motor in real-time via the internet.
- Cloud-Based Data Logging
  – Our system uploads data to a cloud platform (such as ThingSpeak or Blynk), enabling remote access to historical performance data, which most traditional systems do not support.
- Improved Safety and Isolation
  – We incorporate opto-isolators (MOC3021, PC817) and regulated power circuits to enhance safety, protecting both the user and microcontroller from AC power faults.
- User-Friendly Interface
  – The mobile app interface makes the system more accessible and intuitive than conventional knob- or dial-based speed controllers.
- Compact and Modular Design
  – Our project is designed to be compact, scalable, and easily modifiable for different motor capacities or industrial use cases.
- Smart Alerts and Threshold Detection
  – The system can be configured to alert users when values (e.g., current or temperature) exceed predefined thresholds—an intelligent feature missing in older systems.

Conclusion

The proposed IoT-based speed control and monitoring system for a single-phase induction motor successfully combines microcontroller-based TRIAC control with real-time sensing and cloud connectivity. By using voltage, current, and temperature sensors, the system ensures safe and efficient motor operation. The integration of NodeMCU enables remote monitoring and control via a mobile application, enhancing user convenience. Zero-crossing detection ensures precise phase control, resulting in smooth speed regulation. The dual-voltage monitoring adds reliability to the system's feedback loop. This project demonstrates a smart, low-cost solution suitable for industrial and agricultural applications. Future enhancements can include overload protection and integration with AI-based predictive maintenance.

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