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Wi-Fi-based Smart Motor Control: A Low-Cost IoT Solution for Real-Time Induction Motor Operation

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Abstract

This paper presents the design and implementation of a smart wireless motor control system using Wi-Fi technology for real-time remote operation of induction motors. The proposed system integrates a NodeMCU ESP8266 microcontroller, a VFD-based motor driver, a voltage conversion interface, and a mobile application for user-level control. Traditional wired control systems often suffer from installation complexity, limited flexibility, and restricted scalability. To overcome these limitations, the system utilizes Wi-Fi communication to achieve seamless long-distance control and monitoring. A closed-loop feedback mechanism enables real-time Rotation Per Minute (RPM) of the motor shaft regulation and acquisition. The control algorithm processes user commands such as start, stop, forward, reverse, and speed regulation with minimal latency. A voltage regulator ensures proper signal compatibility between the NodeMCU and the VFD reference input. The prototype was constructed and tested under variable load and distance conditions. Experimental results demonstrate high response accuracy, stable wireless communication, and reliable performance. The system reduces wiring requirements and enhances user convenience in industrial and domestic applications. The mobile app interface provides intuitive, user-friendly interaction. The findings validate the feasibility of Wi-Fi-based smart motor control systems for modern automation. The work highlights a cost-effective approach toward future IoT-enabled motor control solutions.

Keywords
Wi-Fi-based control, Induction motor, NodeMCU ESP8266, Remote operation, IoT-enabled automation

1. Introduction
Wired motor control has been common for many years, but modern automation demands better accessibility and reduced maintenance effort. Wireless technology solves many challenges by eliminating complex wiring and offering long-distance control. Among available wireless methods, Wi-Fi provides superior range and bandwidth for industrial motor applications. This research aims to develop a smart Wi-Fi-based motor control system with high reliability and responsiveness. The need is especially relevant in industries. Remote control improves safety by reducing direct interaction with hazardous machinery while enabling centralized monitoring.

1.1 Objectives

- Develop real-time remote-control system that allows precise, real-time motor control from a remote location using Wi-Fi communication,
- Real-time controlling and monitoring of motor rpm, and
- Provide an intuitive as well as user friendly interface for users to easily interact with the system, reducing the complexity of controlling the motor remotely.

2. Literature Review

Several researchers have demonstrated PWM-based DC motor control using microcontrollers such as ATmega16 and Arduino. These systems proved effective but limited in range due to wire or infrared-based communication requirements. IEEE studies also explored Zigbee-based automation, offering mesh topology capabilities but with lower throughput and bandwidth compared to Wi-Fi.

More advanced work implemented PSO-optimized PID controllers and LQR-based speed control algorithms, however most remained simulation-dependent without hardware validation. Research in wireless AC motor control is still limited, particularly when integrating VFD-based frequency regulation and real-time feedback monitoring.

This paper attempts to close that gap by implementing an ESP8266-based real-world hardware setup supporting Wi-Fi remote control, live RPM acquisition, and electrical safety architecture and frequency-controlled speed regulation (Bakibillah et al, 2014, Raka et al, 2014, Dewangan, eta al. 2012, Amer et al. 2014, Adel et al, 2012, Ruba et al. 2012).

3. System Design and Architecture

3.1 Hardware Components

The system has several essential components:

• ESP8266 NodeMCU
• VFD for AC motor control
• PWM to Analog signal converter
• Relay for switching
• Voltage regulator
• RPM sensor
• Smartphone App

3.2 Software Components

- Arduino IDE and Blynk app: Open-Source software to program and smartphone app to run the Microcontroller**.**

3.3 System Flow Diagram

The system consists of several key components including ESP8266 NodeMCU, Variable Frequency Drive (VFD) for AC motor speed control, a PWM-to-Analog Signal Converter for generating the required reference voltage, a Relay Module for switching operations, a Voltage Regulator to supply stable power to the controller, an RPM Sensor to detect motor speed and a Smartphone App used for sending wireless commands and viewing feedback.

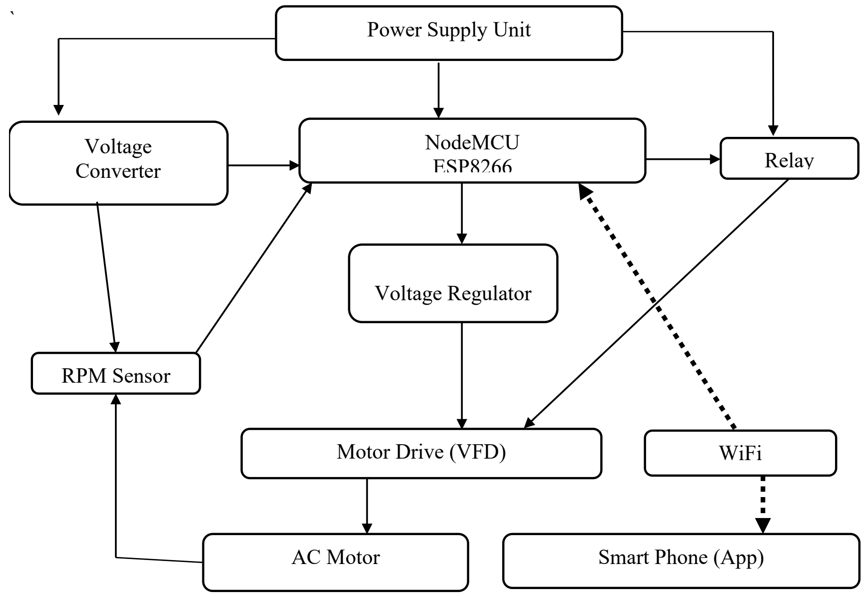

Figure 1. System flow diagram

4. Methods

A simple yet efficient configuration is implemented to enable wireless control of an AC motor. The system integrates key hardware components such as ESP8266 NodeMCU, VFD, relay switching, PWM-to-analog conversion, voltage regulation, an RPM sensor, and a smartphone-based application. Focus was placed on maintaining stable wireless communication, ensuring reliable power delivery, and achieving smooth motor speed response. Special attention was given to signal accuracy, long-range usability, and safe interaction between control electronics and high-voltage motor equipment (Figure 1- Figure 5).

4.1 Operation technique

The wireless remote motor control system was developed beginning with the design of the controller using a NodeMCU microcontroller platform with built-in Wi-Fi. The system was configured to operate an AC motor remotely through a mobile application interface connected over Wi-Fi. All required hardware components were integrated, including the AC motor, VFD motor driver, NodeMCU board, voltage converter, voltage regulator, relay switching unit, and power supply system.

Control commands were sent by the user through the smartphone app and were received by the NodeMCU. The controller processed the command and executed the appropriate action—either starting or stopping the motor via relay activation or adjusting the motor speed by communicating with the VFD. Speed control was achieved by regulating the VFD operating frequency through a reference voltage, which was stabilized using the voltage regulator. A voltage converter was used to match the reference voltage levels between the NodeMCU and the VFD.

During operation, the NodeMCU continuously monitored the motor's rpm through rpm sensor and real-time rpm adjusting and stabilizing variation is done by the controller with rpm sensor feedback according load. After system development, a complete prototype was assembled based on the finalized circuit design. The components were powered, interconnected, calibrated, and tested to ensure proper functioning and reliable signal transmission.

4.2 Circuit Design:

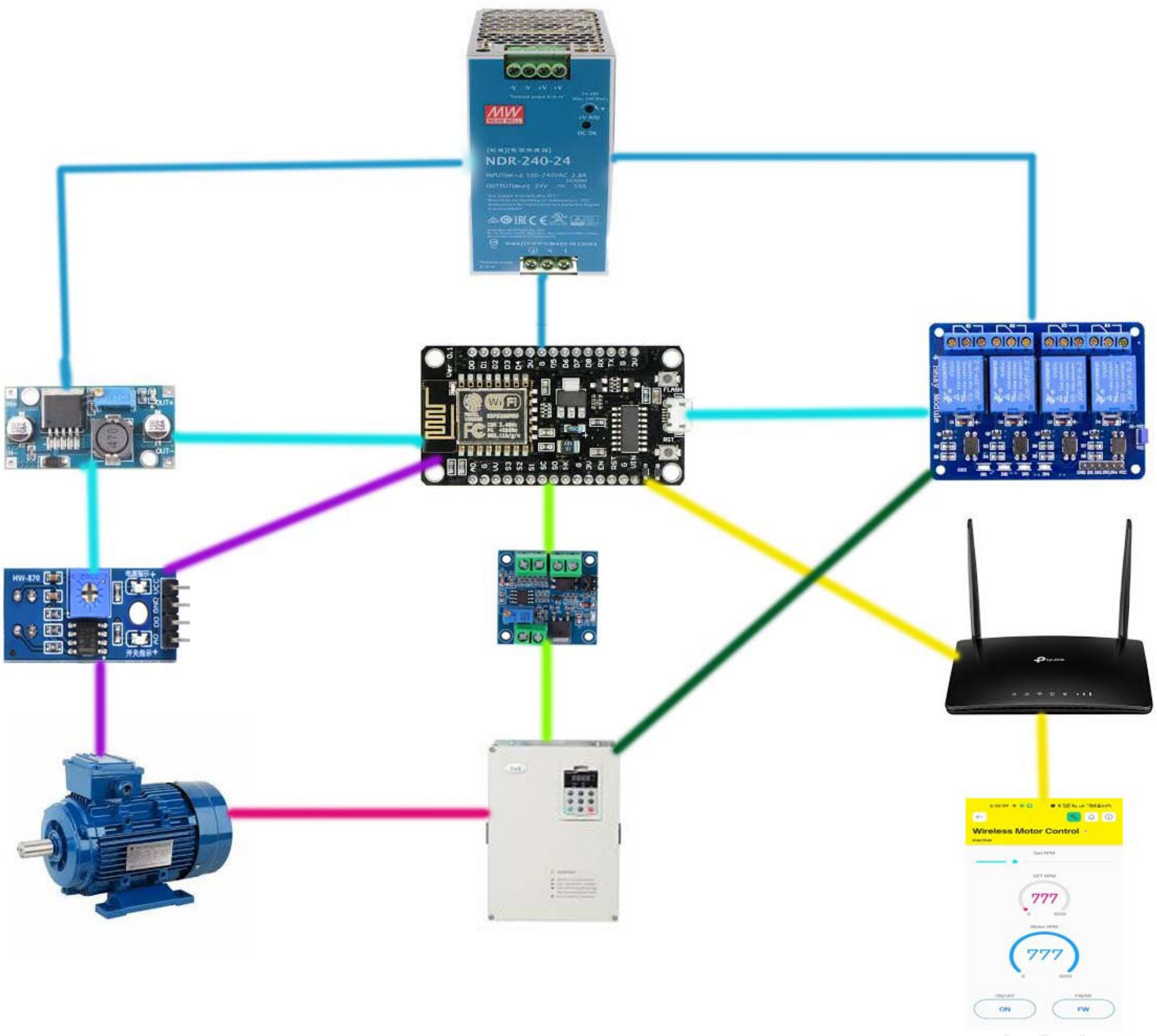

Figure 2. Schematic view of the circuit

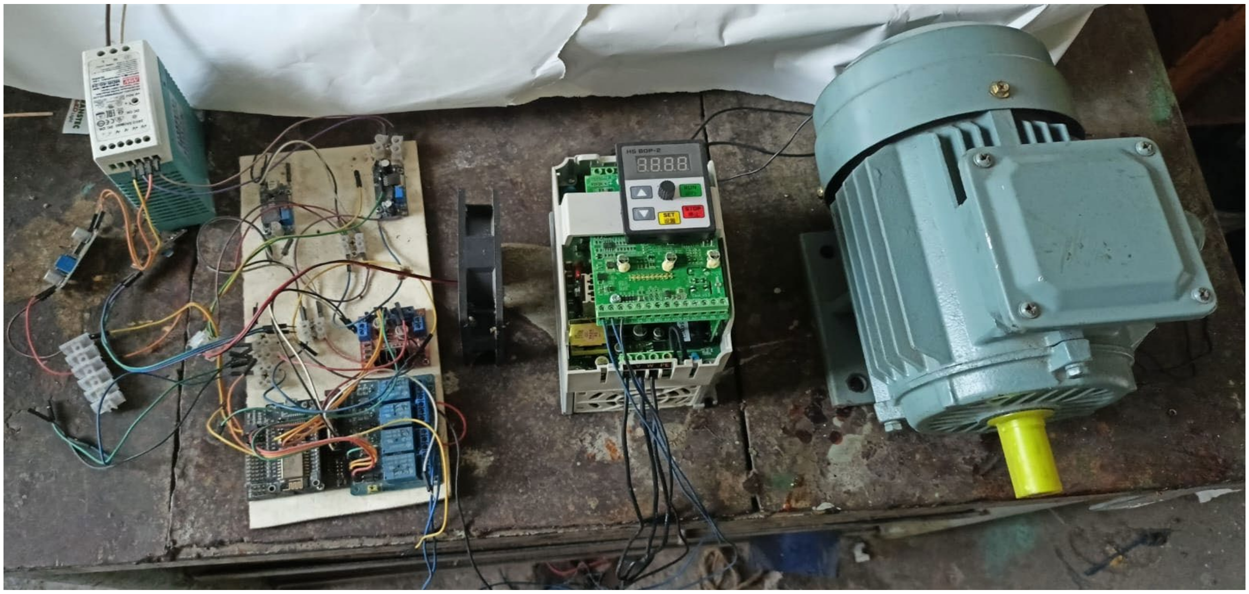

Figure 3. Pictorial view of the circuit

4.4 Algorithms

The wireless motor control system followed a structured control algorithm in which the NodeMCU first initialized the Wi-Fi connection, VFD interface, relay output, voltage converter, sensor input pins and communication with the smartphone app. Once powered, the controller continuously awaited commands sent wirelessly from the mobile interface. When a *start* command was received, the NodeMCU activated the relay to supply power to the motor through the VFD, and upon receiving a *stop* command it immediately disabled the relay to halt motor operation. For speed control, the controller converted the user-defined speed value into a PWM signal, which was then transformed into a 0–10V analog reference and applied to the VFD to regulate motor frequency. Throughout operation, the RPM sensor feedback was read continuously and transmitted to the smartphone for live speed monitoring. The system repeatedly checked power stability, Wi-Fi connectivity and VFD response, and in case of abnormal conditions triggered an emergency shutdown for protection.

5. Testing and Results

After assembling the complete wireless motor control system, a series of performance evaluations were carried out to verify functionality, responsiveness, and operational stability. Testing was initially conducted in a controlled indoor environment to minimize noise interference and ensure safe handling of electrical components. The motor was operated at different speed setpoints through the smartphone interface while monitoring response time, relay switching accuracy, and VFD frequency output. Communication latency was evaluated by measuring the delay between command transmission and motor response, which remained stable and consistently low within the tested range. The system successfully maintained motor operation under varying loads, and feedback from the RPM sensor confirmed smooth and linear speed variation corresponding to the reference voltage applied through the VFD.

Power consumption was measured in both idle and active states, showing efficient operation with minimal overheating or voltage fluctuation. The system also responded reliably when the control distance increased within Wi-Fi coverage, maintaining command stability without signal loss.

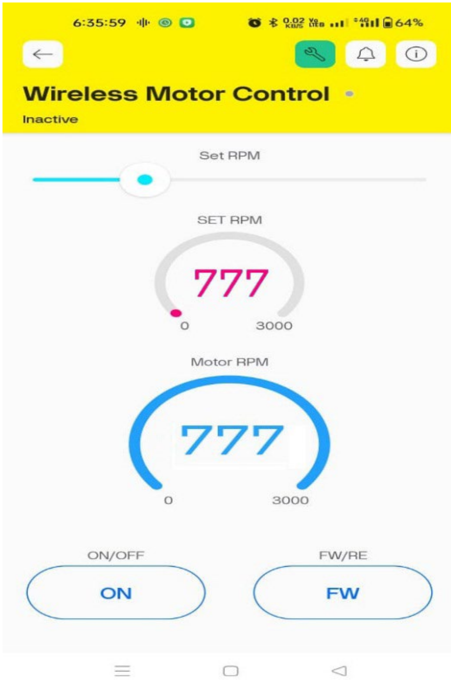

Figure 4. Smart phone app layout

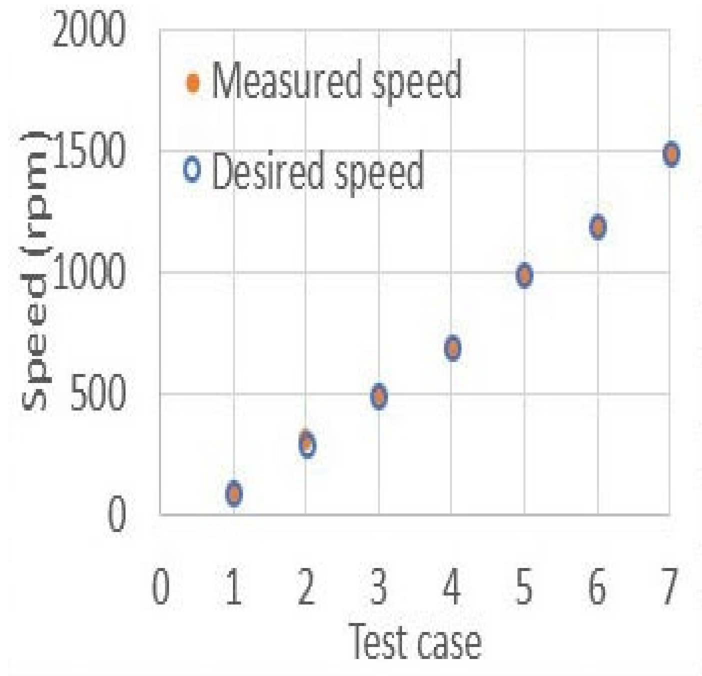

Figure 5. Operational test of motor rpm

6. Conclusion

The development of the wireless motor control system successfully demonstrated that AC motors can be operated, monitored, and controlled remotely using Wi-Fi technology with high reliability and efficiency. By integrating NodeMCU, VFD control, relay switching, voltage conversion, and real-time feedback monitoring, the system provided a safe and flexible alternative to traditional wired motor operation. Testing confirmed smooth speed regulation, low command latency, stable voltage output, and consistent communication performance within Wi-Fi range. The ability to operate the motor without direct physical contact enhances user safety and reduces exposure to high-voltage components or rotating machinery, making the system suitable for industrial, agricultural, and domestic applications. Overall, the completed system offers a scalable foundation for advanced automation solutions, and its successful implementation highlights strong potential for future integration with IoT platforms, data logging, cloud-based analytics, and multi-motor control networks**.**

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Biographies

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