

IoT-Based Predictive Fault Detection and Speed Control of Single-Phase Induction Motor Using VFD and PLC

1. Mohamed Hasan B, 2.Sadhikali S, 3.Abdul Basith S

4.Dr.J.Mohamed Feros Khan, 5.A.Anwar Basha

1,2,3 UG Final Year, 4 Associate Professor, 5 Assistant Professor ,

Department of Electrical and Electronics Engineering, Aalim Muhammed Salegh College of Engineering

ABSTRACT:

The reliability and efficiency of induction motor drives are critical in both industrial and domestic applications. This paper presents an intelligent system that integrates Internet of Things (IoT), artificial intelligence, a Variable Frequency Drive (VFD), and a Programmable Logic Controller (PLC) for real-time speed monitoring, control, and predictive fault detection of a single-phase induction motor. The proposed system continuously acquires operational parameters such as speed, voltage, and current through sensors and transmits them to a cloud platform via an IoT module. Machine learning techniques are applied to analyze the collected data and identify abnormal patterns that indicate potential faults. The PLC executes control actions based on the predictions, ensuring system safety and operational continuity. The implementation demonstrates improved energy efficiency, reduced downtime, and enhanced reliability compared to conventional motor control systems.

Keywords

IoT, Predictive Maintenance, Induction Motor, VFD, PLC, Machine Learning, Fault Detection

1. INTRODUCTION

Induction motors play a vital role in modern industrial and domestic applications due to their robust construction, low cost, and minimal maintenance requirements. Among them, single-phase induction motors are extensively used in small-scale industries, household appliances, irrigation systems, and HVAC applications. Despite their advantages, these motors are often operated under varying load and environmental conditions, making them susceptible to faults such as overcurrent, overheating, voltage fluctuations, and mechanical wear. These issues can lead to unexpected failures, reduced efficiency, and increased maintenance costs if not addressed in a timely manner.

Conventional motor monitoring and control techniques primarily rely on manual inspection or basic protection mechanisms such as overload relays and circuit breakers. While these methods provide a certain level of protection, they are reactive in nature and fail to detect early-stage faults. As a result, there is a growing need for intelligent systems capable of continuous monitoring, early fault prediction, and automated control to enhance system reliability and operational efficiency.

The emergence of the Internet of Things (IoT) has enabled real-time data acquisition and remote monitoring of electrical systems. By integrating sensors and communication modules, IoT facilitates continuous tracking of critical parameters such as motor speed, current, voltage, and temperature. However, IoT alone

is insufficient for intelligent decision-making unless combined with advanced data analysis techniques.

In this context, artificial intelligence (AI) and machine learning algorithms have gained significant attention for their ability to analyze large volumes of data and identify hidden patterns associated with fault conditions. By training models using historical and real-time data, it becomes possible to predict potential failures before they occur, enabling predictive maintenance strategies. This not only minimizes downtime but also extends the lifespan of the motor.

In addition to monitoring and prediction, effective control of motor operation is equally important. A Variable Frequency Drive (VFD) provides precise speed control by varying the supply frequency, thereby improving energy efficiency and operational flexibility. Meanwhile, a Programmable Logic Controller (PLC) ensures reliable and deterministic control of the system by executing predefined logic based on real-time inputs and AI-based predictions.

This paper proposes an integrated system that combines IoT-based monitoring, AI-driven predictive fault detection, and PLC-based automation for the speed control of a single-phase induction motor using a VFD. The system continuously acquires operational data through sensors, processes it using intelligent algorithms, and takes appropriate control actions to maintain safe and efficient operation. By bridging the gap between monitoring, prediction, and control, the proposed approach represents a significant step towards

smart and autonomous motor drive systems aligned with Industry 4.0 principles.

2. Literature Survey

The advancement of intelligent monitoring and control systems for electric motors has gained significant attention in recent years due to the increasing demand for reliability, efficiency, and automation. Early research on induction motor fault detection focused on conventional techniques such as vibration analysis, thermal monitoring, and motor current signature analysis, which required expert interpretation and offline processing. A comprehensive survey of such traditional condition monitoring methods is presented in [2].

With the rapid development of the Internet of Things (IoT), real-time monitoring systems have been widely adopted for industrial applications. IoT-based solutions enable continuous acquisition and remote visualization of motor parameters such as voltage, current, and temperature. Studies have demonstrated that IoT-based motor health monitoring systems significantly improve maintenance efficiency and system visibility [1], [9]. However, these systems are often limited to data collection and lack intelligent decision-making capabilities.

To address this limitation, machine learning techniques have been introduced for predictive maintenance. Approaches based on Support Vector Machine, Random Forest, and Artificial Neural Networks have shown high accuracy in fault classification and early prediction of motor failures. The effectiveness of machine learning for predictive maintenance using multi-classifier approaches is discussed in [3], while recent reviews highlight the growing role of AI in induction motor fault diagnostics [5]. Furthermore, advanced techniques combining signal processing and neural networks have been successfully applied for fault feature extraction and classification in motor monitoring systems [6].

In addition to monitoring and prediction, efficient motor control plays a crucial role in enhancing system performance. The use of Variable Frequency Drive has become widespread due to its ability to provide precise speed control and improve energy efficiency. Similarly, Programmable Logic Controller-based automation ensures reliable and real-time control in industrial environments. These technologies form the backbone of modern industrial automation systems.

Recent research trends focus on integrating IoT and machine learning to develop intelligent predictive maintenance frameworks. Studies have shown that

combining IoT data acquisition with AI-based analytics significantly enhances fault detection accuracy and reduces downtime [4], [8]. Emerging concepts such as digital twins further extend these capabilities by enabling real-time simulation and monitoring of motor performance [10].

Despite these advancements, most existing works address monitoring, prediction, or control independently. There is limited research on fully integrated systems that combine IoT-based monitoring, AI-driven fault prediction, and PLC-based control with VFD for real-time implementation. Therefore, the proposed work aims to bridge this gap by developing a comprehensive and intelligent system for predictive fault detection and speed control of a single-phase induction motor.

3. PROPOSED SYSTEM BLOCK DIAGRAM

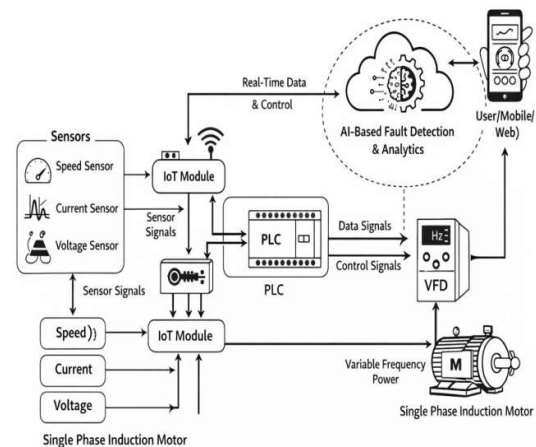


Fig.3.1 Block Diagram of proposed system

The proposed system consists of three major layers: data acquisition, intelligent processing, and control execution.

In the data acquisition layer, sensors are used to measure motor parameters such as speed, current, and voltage. These signals are interfaced with a microcontroller-based IoT module, which transmits the data to a cloud server.

The intelligent processing layer applies machine learning algorithms to analyze the incoming data stream. The model is trained using both normal and faulty operating conditions to classify the motor's health status.

The control execution layer includes a PLC and a VFD. The PLC receives commands based on AI predictions and accordingly regulates the VFD to adjust motor speed or shut down the system in case of critical faults.

4. METHODOLOGY

The methodology begins with continuous data acquisition from sensors installed on the motor. The collected data is preprocessed to remove noise and normalize the values. Feature extraction techniques are applied to derive meaningful indicators such as current variation, speed deviation, and voltage fluctuation.

A supervised machine learning model is trained using labeled datasets representing different operating conditions. Once trained, the model is deployed to classify real-time data into normal or faulty categories.

Based on the classification results, control signals are generated. If a potential fault is detected, the system issues an alert and initiates corrective action through the PLC. The VFD then adjusts the motor speed or disconnects the supply depending on the severity of the fault.

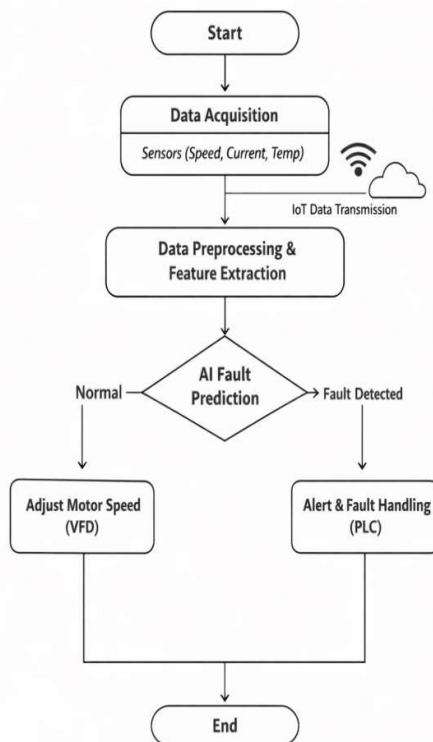


Fig 4.1 Flow chart of proposed system

5. IMPLEMENTATION AND RESULTS

The experimental evaluation of the proposed system on a 1 HP single-phase induction motor demonstrates its effectiveness in real-time monitoring, intelligent fault prediction, and automated control. Under no-load, light-load, and rated-load conditions, the motor operates within normal limits, maintaining stable speed and acceptable current and temperature levels,

while the VFD ensures efficient speed regulation. As the operating conditions deviate, such as during overload, voltage drop, and elevated temperature scenarios, the AI model successfully identifies early warning signs by analyzing variations in current, speed, and thermal behavior. In these cases, the PLC initiates preventive actions including speed reduction and alarm activation to avoid further deterioration.

During severe fault conditions, such as excessive overcurrent or sensor failure, the system responds promptly by tripping the motor to ensure safety and prevent damage. The results clearly indicate that temperature rise and current variation serve as key indicators for fault progression.

A comparative analysis with conventional systems shows that the proposed approach offers improved accuracy in fault detection, enhanced operational safety, and better energy efficiency. The system also provides scalability for future expansion and integration with advanced industrial automation platforms.

Overall, the results confirm that the proposed system is capable of delivering a robust, intelligent, and efficient solution for motor monitoring and control, making it suitable for modern smart industry applications.

S.No	Condition	Voltage (V)	Current (A)	Speed (RPM)	Temperature (°C)	AI Prediction	PLC Action
1	No Load	230	2.1	1440	32	Normal	Motor Runs at Set Speed
2	Light Load	228	3.0	1425	36	Normal	Speed Maintained
3	Rated Load	225	4.5	1400	42	Normal	VFD Maintains Speed
4	Overload Condition	220	6.2	1350	55	Warning	Speed Reduced + Alarm ON
5	High Temperature	230	5.8	1380	70	Warning	Cooling Alert + Speed Reduced
6	Voltage Drop	200	6.5	1300	60	Warning	Speed Adjusted
7	Severe Overcurrent	210	8.0	1200	75	Fault	Motor Trip (Shutdown)
8	Sensor Fault Case	230	—	—	—	Fault	System Halt + Alert

Table 5.1 Experimental Results of proposed system

5. ADVANTAGES OF THE PROPOSED SYSTEM

The developed system offers several advantages:

Real-time monitoring and remote accessibility

Early fault detection and predictive maintenance

Improved energy efficiency through optimized speed control

Reduced manual intervention and maintenance cost

Enhanced system reliability and safety

6. CONCLUSION

This paper presents a smart and efficient solution for induction motor monitoring and control using IoT and artificial intelligence. The integration of predictive fault detection with automated control using PLC and VFD significantly enhances system performance and reliability. The results confirm that the proposed approach is effective in identifying potential faults and taking timely corrective actions.

7. FUTURE SCOPE

Future work can focus on incorporating advanced deep learning techniques for more accurate fault prediction. The system can also be extended to three-phase motors and integrated with SCADA systems for large-scale industrial applications. Additionally, edge computing can be implemented to reduce latency and improve real-time performance.

References

- [1] M. Yousuf, T. Alsuwian, A. A. Amin, S. Fareed, and M. Hamza, "IoT-based health monitoring and fault detection of industrial AC induction motor for efficient predictive maintenance," *Measurement and Control*, vol. 57, no. 8, pp. 1146–1160, 2024
- [2] P. Zhang, Y. Du, T. G. Habetler, and B. Lu, "A survey of condition monitoring and protection methods for medium-voltage induction motors," *IEEE Transactions on Industry Applications*, vol. 47, no. 1, pp. 34–46, 2010
- [3] G. A. Susto, A. Schirru, S. Pampuri, S. McLoone, and A. Beghi, "Machine Learning for Predictive Maintenance: A Multiple Classifier Approach," *IEEE Transactions on Industrial Informatics*, vol. 11, no. 3, pp. 812–820, 2015.
- [4] M. Mohammed, O. Abdulateef, and A. Hamad, "An IoT and machine learning-based predictive maintenance system for electrical motors," *Journal Européen des Systèmes Automatisés*, vol. 56, no. 4, pp. 651–656, 2023.

- [5] C. E. Sunal, V. Dyo, and V. Velisavljevic, "Review of machine learning-based fault detection for induction motors," *IEEE Access*, vol. 10, pp. 71344–71355, 2022.
- [6] M. Zuhaib et al., "Fault feature extraction using discrete wavelet transform and artificial neural network for induction motor monitoring in IoT environment," *Energies*, vol. 15, no. 21, 2023.
- [7] M. Azamfar, J. Singh, I. Bravo-Imaz, and J. Lee, "Multisensor data fusion for gearbox fault diagnosis using convolutional neural networks," *Mechanical Systems and Signal Processing*, vol. 144, 2020.
- [8] O. Saleh et al., "Improving predictive maintenance in industrial environments via IIoT and machine learning," *International Journal of Advanced Computer Science and Applications*, vol. 15, 2024.
- [9] M. Şen and B. Kul, "IoT-based wireless induction motor monitoring," in *Proc. IEEE Int. Scientific Conf. Electronics (ET)*, 2017, pp. 1–5
- [10] "Digital twin innovations for induction motor monitoring and predictive maintenance: A 2020–2025 review," *Next Research*, vol. 2, no. 4, 2025.