International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 10 Issue: 10 | Oct - 2026 SJIF Rating: 8.659 ISSN: 2582-3930

Low-Cost Predictive Maintenance System for Small-Scale Industries

G.Srikanth[1] , N.Syamala Devi[2], Manisha[3], Karthik[4], Venkatesh[5]
Department of Electronics and Communication Engineering, CMR Technical Campus, Hyderabad, India
[1] G.Srikanth— gimmadi.srikanth@gmail.com
[2] N.Syamala Devi — nsyamaladevi05@gmail.com
[3] Manisha — manishagoud921@gmail.com
[4] Karthik — karthikkattula05@gmail.com
[5] Venkatesh — venkateshkopanti33@gmail.com

Abstract - Predictive maintenance helps prevent machines from breaking down suddenly, but many small businesses can't pay for costly monitoring tools.This paper introduces a low-cost system for predictive maintenance using an ESP32 microcontroller.The main sensor is an ADXL345, which measures vibration in rotating machines.Another sensor, the ACS712, can track changes in the machine's current.The ESP32 gathers data from these sensors, uses simple rules to check if the machine is working properly, and shows the machine's status on an OLED screen.It also lights up an LED and sounds a buzzer when it detects something wrong.The ESP32 can connect to Wi-Fi, sending the data to a web dashboard for monitoring from anywhere.During testing, vibration levels of 0.90, 3.63, and 23.41 showed normal, warning, and faulty conditions, respectively.This system shows that a simple and affordable setup can help small industries monitor their machines and get early warnings about problems. Keywords— Predictive maintenance, ESP32, ADXL345, vibration monitoring, IoT, small-scale industry, fault detection

Key Words: Predictive maintenance, ESP32, ADXL345, vibration monitoring, IoT, small-scale industry, fault detection

1.INTRODUCTION

Industry 4.0 is making industrial machines more connected and data-driven. One important part of this change is predictive maintenance, where the condition of a machine is monitored continuously and maintenance is planned before a serious failure occurs. Vibration is a useful parameter for this purpose because faults in rotating machines often produce changes in vibration.

In many small-scale industries, maintenance is still mainly reactive or preventive. Reactive maintenance means the machine is repaired after a breakdown, while preventive maintenance is usually carried out at fixed time intervals. Both approaches have limitations. Sudden failures can stop production, and fixed-interval maintenance may result in unnecessary servicing. Manual inspection can also miss small changes that occur between inspections.

Large industries can use SCADA and PLC-based monitoring systems, but these systems can be expensive and may require specialized installation and maintenance. Therefore, this work focuses on a low-cost alternative using ESP32, which has built-in Wi-Fi and enough processing capability for basic sensor analysis.The proposed system is mainly intended for motors, pumps, fans, and other rotating equipment used in small-scale industries.

2.Related works

Positive habits such as IoT and vibration sensing can be developed as part of national preparedness to contribute to the nation.Previous studies have shown that low-cost IoT systems have been developed to collect vibration data and identify abnormal machine behavior.Wireless monitoring has also been used for electric motors, generators, induction motors, rotating machinery, and conveyor systems.Edge-based approaches process some data near the machine so that alerts can be generated quickly.From the reviewed work, a common observation is that continuous sensor monitoring can improve the detection of mechanical problems such as imbalance, misalignment, looseness, and bearing wear.However, many advanced systems use multiple sensors, cloud processing, or machine-learning models, which can increase implementation complexity.The present work keeps the prototype simple by using an ESP32 with vibration monitoring and threshold-based fault classification, making it easier for students and small industries to implement.

Work	Main idea	Observation
Kolok et al. (2025)	Low-cost IoT predictive maintenance using vibration	Shows the usefulness of vibration for early fault detection.
Magadán et al. (2023)	Wireless monitoring of electric motors	Reduces wiring and supports remote condition monitoring.
Swathi et al. (2020)	IoT monitoring of generators	Uses continuous sensor data for maintenance decisions.
Kumar et al. (2023)	Edge-based motor fault detection	Local processing can reduce delay in fault detection.
Rajesh et al. (2024)	IoT predictive maintenance for conveyors	Shows that IoT monitoring can be extended to different machines.

3. PROPOSED SYSTEM

The ADXL345 is fixed to the machine so that it can sense vibration in the X, Y, and Z directions. The ESP32 reads these values through I2C communication. The collected data is converted into a vibration magnitude and compared with predefined limits. The system then decides whether the machine condition is normal, warning, or fault. The SSD1306 OLED display gives local information to the operator. When the measured value goes above the warning or fault limit, the ESP32 activates an LED and buzzer. At the same time, Wi-Fi can be used to send the readings to a web or IoT dashboard. This provides a simple way to observe machine behavior over time.

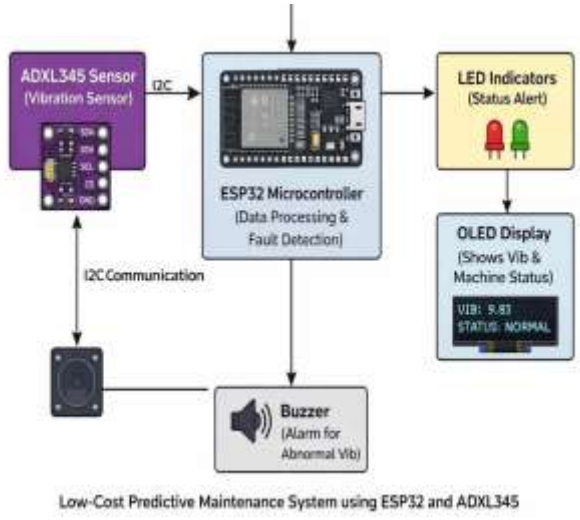


Fig:1- Prototype/system representation

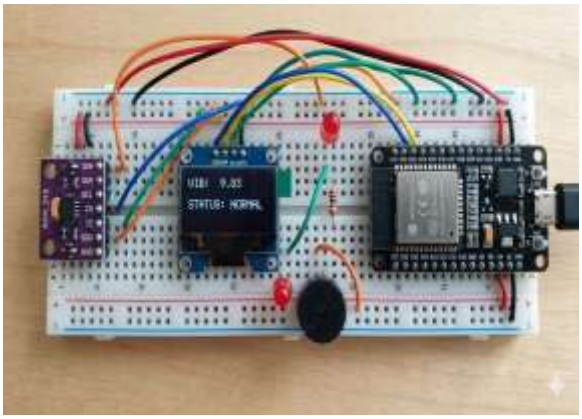


Fig:2-Circuit/prototype arrangement.

4.METHODOLOGY

A. Sensor Data Acquisition

The ADXL345 accelerometer is mounted on the machine under observation. It measures acceleration along three axes. Changes in these readings are used to observe the vibration condition of the machine. If current monitoring is required, the ACS712 provides the current signal to the ESP32 through an analog input.

B. Data Processing

The ESP32 receives the sensor readings and performs basic processing. The vibration readings are checked against threshold values obtained from the prototype testing and machine operating condition. A low value is treated as normal, an increased value is treated as warning, and a high value is treated as a fault condition. This approach is simple and does not require a high-end processor.

C. Local Indication and Alert

The processed values are shown on the 128×64 SSD1306 OLED display. The display can show vibration, current, and machine status. When an abnormal value is detected, the LED is turned on and the buzzer produces an audible warning. This gives the operator an immediate indication even without opening the dashboard.

D. IoT Communication

The ESP32 uses its built-in Wi-Fi to transmit the processed data to a remote monitoring interface. Depending on the implementation, HTTP or MQTT can be used. The dashboard can display current values and historical trends so that an operator can observe changes in machine behavior.

5.Hardware and Software

A.Hardware

ESP32 development board – central controller with built-in Wi-Fi and Bluetooth. ADXL345 accelerometer – three-axis vibration sensing. ACS712 current sensor – measures machine current whencurrent monitoring is included. SSD1306 OLED – 128×64 local display for sensor values and status. LED and buzzer – visual and audible fault indicators. Breadboard, jumper wires and 220 Ω resistor – used for prototype connections and LED current limiting.

B.Software

The prototype is programmed using the Arduino IDE. The software uses the Wire library for I2C communication and sensor/display libraries for the ADXL345 and SSD1306. Wi-Fi communication is handled by the ESP32 networking support. The program repeatedly reads the sensors, calculates the required values, checks the thresholds, updates the display, controls the alerts, and sends data for remote monitoring.

6.EXPERIMENTAL RESULT

The system successfully monitored vibration levels and displayed the results in real time. Under normal conditions, the vibration value was 0.90, indicating stable operation.

During warning conditions, the vibration value increased to 3.63, indicating abnormal vibrations.Under fault conditions, the vibration value reached 18.09, indicating a possible machine fault.The system effectively identified different operating conditions, enabling early fault detection and predictive maintenance.



Fig: 3- Normal operating condition.



Fig:4 -Warning operating condition.



Fig:5 -Fault operating condition.

The prototype was tested by observing different vibration conditions. The dashboard used three practical operating states: NORMAL, WARNING, and FAULT. A vibration value of 0.90 was observed in the normal condition. A value of 3.63 was used to represent a warning condition, while a value of 23.41 represented a fault condition. These values are prototype threshold examples and should be recalibrated for a particular machine before industrial deployment.

Observed vibration	System state	Action
0.90	NORMAL	Machine continues normal monitoring.
3.63	WARNING	Operator should inspect the machine.
23.41	FAULT	Immediate attention/maintenance is required.

7.Discussion

The main benefit of this system is that it is not very expensive and is easy to build.The ESP32 does both processing and sending signals wirelessly on one board, so you don't need extra parts.The ADXL345 measures vibrations in three directions, which helps in finding changes in moving machines.The OLED screen, LED light, and buzzer make it easier for someone to understand what the system is doing.

The current version of the system mainly checks for vibrations above a certain level.
This works well for showing the basic idea, but it can't catch all machine problems accurately.Each machine needs to be checked separately because normal vibration levels depend on things like the type of machine, how it's fixed, how fast it runs, how much it's loaded, and where the sensor is placed.To make a better system for predicting when machines need maintenance, more data should be collected over a longer time and analyzed using things like average vibration, highest peaks, frequency changes, or even machine learning.

8.Conclusion

A low-cost predictive maintenance prototype using ESP32 was developed for small-scale industrial applications. The system uses an ADXL345 accelerometer to monitor machine vibration and can include an ACS712 current sensor for additional condition information. The ESP32 processes the sensor readings and gives local and remote indications through the OLED, LED, buzzer, and IoT dashboard. The prototype successfully demonstrated normal, warning, and fault conditions using different vibration levels.
The proposed approach can help small industries move from breakdown-based maintenance toward condition-based maintenance without the cost and complexity of large industrial monitoring systems. The present work is a

prototype, so further testing on real industrial machines is needed before using it as a safety-critical maintenance system.

8. FUTURE SCOPE

- Add temperature, humidity, acoustic, pressure, and improved current sensing for multi-parameter monitoring.
- Collect long-term machine data and use RMS, FFT, and other vibration features for better fault identification.
- Use machine-learning or anomaly-detection methods for machine-specific predictive maintenance.
- Add SMS, e-mail, or mobile notifications for urgent alerts.
- Replace the breadboard prototype with a PCB and suitable industrial enclosure.
- Connect multiple monitoring nodes to one IIoT platform for factory-level condition monitoring.

Improve data security using authentication and encrypted communication.

REFERENCES

[1] P. Kolok, M. Hodoň, P. Ševčík, L. Hotz, and N. Remy, "Low-Cost IoT-Based Predictive Maintenance Using Vibration," Sensors, vol. 25, no. 1, p. 4595, 2025.

[2] L. Magadán, F. J. Suárez, J. C. Granda, and D. F. García, "Low-Cost Industrial IoT System for Wireless Monitoring of Electric Motors Condition," Mobile Networks and Applications, vol. 28, pp. 97–106, 2023.

[3] D. Swathi, T. A. Kumar, and M. D. Yaseen, "IoT Based Condition Monitoring of Generators and Predictive Maintenance," Proc. 2nd Int. Conf. on Communication and Electronics Systems (ICCES), pp. 621–626, 2020.

[4] R. Kumar, S. Natarajan, and P. Mehta, "Edge-Based Fault Detection in Electric Motors Using IoT," Mobile Networks and Applications, vol. 28, no. 3, pp. 245–251, 2023.

[5] Lee and H. Kim, "Condition Monitoring of Induction Motors Using IoT," IEEE Sensors Journal, vol. 23, no. 6, pp. 4125–4133, 2023.

[6] M. Singh and R. Patel, "Condition Monitoring of Induction Motors Using IoT," International Journal of Engineering Research, vol. 12, no. 4, pp. 98–104, 2023.

[7] P. Sharma and V. Gupta, "IoT-Based Real-Time Condition Monitoring of Induction Motors," International Journal of Advanced Research in Electrical and Electronics Engineering, vol. 11, no. 2, pp. 55–60, 2022.

[8] J. Lee and H. Kim, "Industrial IoT-Based Health Monitoring of Rotating Machinery," IEEE Access, vol. 9, pp. 118345–118354, 2021.

[9] S. Rajesh, P. Karthik, and R. Kumar, "IoT-Based Predictive Maintenance for Conveyor Systems," SSRG International Journal of Electrical and Electronics Engineering, vol. 11, no. 4, pp. 15–21, 2024.