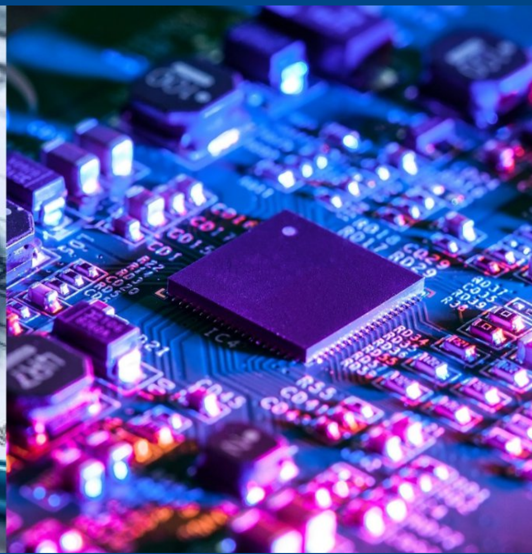
ISSN: 2582-7219

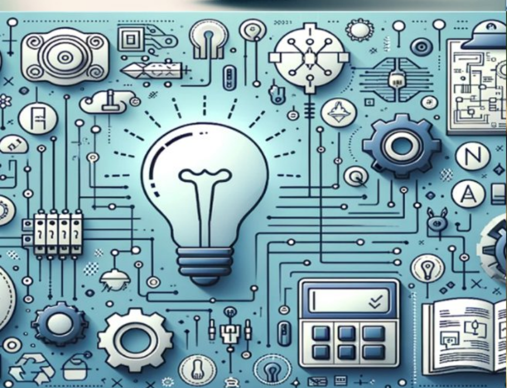




International Journal of Multidisciplinary Research in Science, Engineering and Technology

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)



Impact Factor: 8.206

Volume 9, Issue 4, April 2026

www.ijmrset.com | ijmrset@gmail.com | +91 6381 907 438 | +91 63819 07438

ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 8.206| ESTD Year: 2018|

International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

Power Line Inspection and Maintenance Robot using IoT with Image Processing

Mohammed Rafiullah R, Mohammed Kais K, Mohammed Taufiq A, Mohamed Idrish S

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

Chennai, Tamil Nadu, India

ABSTRACT: As with any preventive maintenance technology, the efforts spent on status monitoring are justified by the reduction in fault occurrence and the elimination of losses due to power disruptions. This paper presents a cohesive multidisciplinary effort involving sensing, signal processing, and robotics to patrol power cable networks. The proposed system utilizes a robotic platform equipped with a NodeMCU for electrical parameter sensing and an ESP32-CAM for real-time image processing. Unlike traditional trial-and-error methods, this robot identifies the exact location of open and short-circuit faults, displaying the distance in kilometers at a base station. By replacing human workers in dangerous live-line operations, the system enhances both reliability and safety.

KEYWORDS: Power Line Inspection, IoT, ESP32-CAM, NodeMCU, Fault Localization, Image Processing, Live Line Maintenance.

I. INTRODUCTION

The primary aim of this project is to detect and locate faults in cable lines accurately. In modern urban areas, electricity transmission through underground or overhead cables is efficient but makes manual fault detection difficult. When a fault occurs, existing methods often rely on cumbersome algorithms or manual inspection, leading to significant time consumption.

This work addresses these challenges by introducing a mobile monitoring platform carrying a sensor array. The robot continuously patrols the network to locate incipient failures and estimate the aging status of insulation. By integrating IoT and cloud monitoring, the system ensures that current values and fault statuses are updated automatically without manpower interruption.

II. LITERATURE SURVEY

The development of this system was informed by a comprehensive review of existing methodologies:

1. **Underground Cable Fault Detection (2019):** Iyer and Rao presented a technique using Wavelet transforms to identify fault phases in simulated signals. While accurate in simulation, it lacked a physical robotic deployment mechanism
2. **Cable Fault Monitoring (2018):** Talwar and Kulkarni constructed decision algorithms using Wavelet coefficients to indicate fault types with satisfactory accuracy.
3. **IoT Based Power Management (2019):** Shankar et al. demonstrated the use of programmed controllers and network ports to collect device power levels, which served as a foundation for our cloud-based monitoring.
4. **Power Factor Correction (2019):** Thamizharasan et al. utilized PIC microcontrollers and IoT for web monitoring of power quality, highlighting the effectiveness of relay drivers in automated electrical systems.

III. PROPOSED METHODOLOGY

The proposed system moves beyond manual calculation to an automated, cloud-synced robotic solution.

Fault Detection Logic

The system creates a fault simulation environment using a series of voltage dividers. In the event of a short circuit, the voltage across these resistors changes. This change is fed into an ADC, which provides precise digital data to the

ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 8.206| ESTD Year: 2018|

International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

programmed NodeMCU. The controller then calculates the exact distance to the fault in kilometers.

Robotic Movement and Control

The robot's movement is directed by the user through a web interface. Relays are controlled by relay drivers to operate DC motors, allowing the robot to navigate along the power lines.

Power System

To support the electronics, the robot includes a robust power supply unit:

Step-down Transformer: Converts 230V to 12V AC.

Bridge Rectifier&Filter: Converts AC to stable DC.

Voltage Regulator(IC7805): Ensures a consistent 5V supply for the microcontrollers.

IV. HARDWARE ARCHITECTURE

The ESP32-CAM Subsystem

The ESP32-CAM is the "eyes" of the robot. It handles live video streaming via WebSockets, providing a real-time view of the infrastructure. By utilizing a dual-task architecture, the module handles Wi-Fi communication and camera capture on separate cores to minimize latency.

The NodeMCU (ESP8266) Subsystem

The NodeMCU acts as the primary data acquisition unit. It interfaces with current sensors to monitor the transmission line's status. It categorizes the current into three states:

Over Current Under Current

Sparking Current Fault

Mechanical Suspension and Stability

To ensure the robot remains stable while hanging, the design uses a two-point suspension system. A spreader bar is incorporated to prevent rotation and dampen the pendulum motion that can occur during movement.

Challenges and Failures Faced

The development process involved several iterations to overcome technical hurdles:

1) **Camera Initialization Failures:** Noise from the DC motors initially corrupted the camera's communication. This was solved by adding decoupling capacitors and separating the motor and logic power grounds.
2) **PWM Timing Instability:** Generating PWM signals directly from the microcontroller caused motor jitter during high Wi-Fi activity. The team transitioned to using an external **PCA9685 PWM driver**, which offloads timing generation and ensures smooth movement.
3) **Voltage Measurement Drift:** Initial resistive divider circuits showed drift due to temperature changes. The solution involved
4) using precision resistors with low temperature coefficients and software-based calibration.
5) **Battery Management:** To prevent damaging the 12V $LiFePO_4$ battery, an undervoltage lockout circuit was added to disconnect the load when voltage drops below a safe threshold.

V. RESULTS AND DISCUSSION

Experimental results confirm that the robot can identify fault positions which can then be easily noted for repair or replacement.

Resource Utilization

The hardware resource usage remained efficient, allowing the NodeMCU to maintain a persistent connection to the cloud while the ESP32-CAM streamed video at 15–20 FPS.

ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 8.206| ESTD Year: 2018|

International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)
(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

Comparison with Existing Systems

Table I. Comparison with Existing Systems

Feature	Manual/Megger Method	IoT Robotic System
Effort	High human effort	Automated patrolling
Time	High consumption	Real-time updates
Accuracy	Trial and error	Digital localization
Data	Manual logging	Cloud-based monitoring

VI. SYSTEM ARCHITECTURE

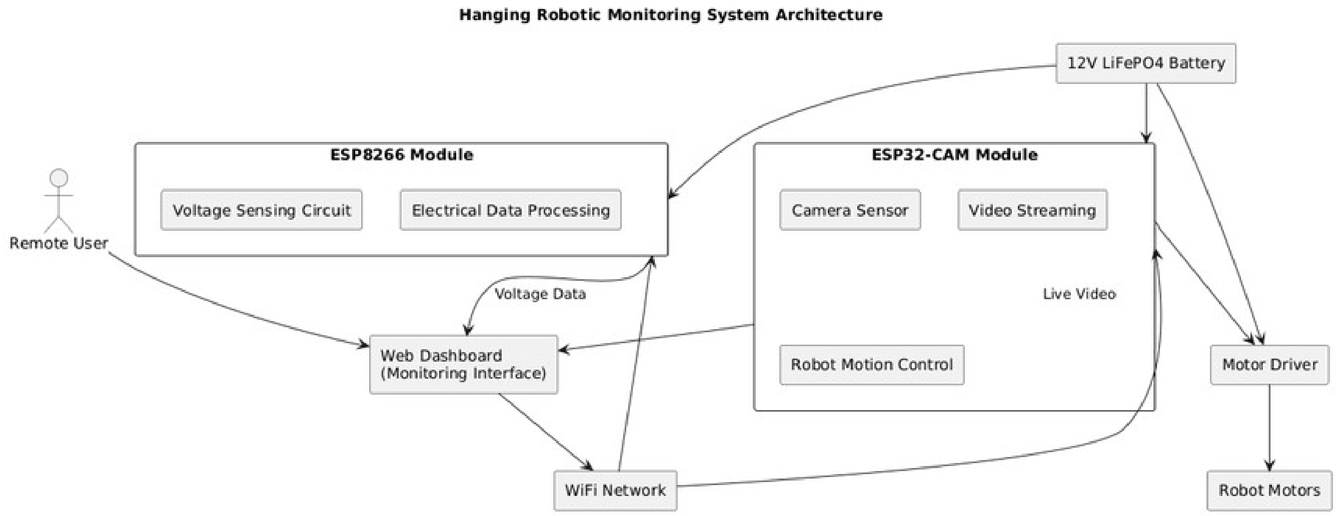
The ESP32-CAM operates as the primary controller and video server. It runs a dual-task firmware architecture similar to that documented in community implementations , with one task handling Wi-Fi communication and command processing while a lower-priority task manages camera capture and streaming. This separation ensures that control commands receive priority treatment, minimising latency even when video streaming consumes significant processing resources.

Motor control is implemented through a PCA9685 PWM driver connected to the ESP32-CAM via I2C, following the pattern established in existing firmware . This offloads precise timing generation from the ESP32, ensuring stable servo or DC motor operation regardless of variations in Wi-Fi or camera processing load. The PCA9685 provides up to 16 channels of 12-bit PWM output, sufficient for controlling multiple motors or positioning servos for camera aiming.

ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 8.206| ESTD Year: 2018|

International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)



VII. FUTURE WORK

Short-term enhancements include the integration of thermal imaging to detect overheating components not visible to the standard OV2640 sensor. Long-term, the system can be integrated into "Digital Twin" facility models, where the robot acts as a mobile sensor node updating a 3D representation of the power grid in real-time.

VIII. CONCLUSION

This project successfully demonstrates a lightweight hanging robotic system for power line inspection. By integrating ESP32-CAM for visual monitoring and NodeMCU for electrical parameter acquisition, the system provides a robust, low-cost alternative to dangerous manual inspections. The 12V $LiFePO_4$ battery ensures long operational life, while the dual-microcontroller architecture ensures that video processing does not interfere with critical fault detection. This system represents a significant step toward the democratization of robotic inspection technology in industrial maintenance.

REFERENCES

1) D. N. Iyer and K. A. R. Rao, "Underground Cable Fault Detection and Monitoring System," 2019.
2) P. D. Talwar and S. B. Kulkarni, "Cable Fault Monitoring and Indication," 2018.
3) R. Shankar et al., "IoT Based Multi-Utility Auto Cut-Off Power Charger," 2019.
4) R. Thamizharasan et al., "Automatic Power Factor Correction and Monitoring using IoT," 2019.
5) Hebei University of Technology, "Operating platform system used for high-rise building robot," Chinese Patent CN104746864A, 2015.
6) C. Barroso-Fernández et al., "Time-Sensitive IIoT Flows over Wi-Fi," IEEE Internet of Things Journal, 2025.

INTERNATIONAL JOURNAL OF

MULTIDISCIPLINARY RESEARCH

IN SCIENCE, ENGINEERING AND TECHNOLOGY

| Mobile No: +91-6381907438 | Whatsapp: +91-6381907438 | ijmrset@gmail.com |

www.ijmrset.com