

IOT – POWERED ADAPTIVE LIGHTING SYSTEM FOR INDUSTRIAL FACILITIES

**Dr. S. Chandrashekhar Reddy¹, G. Vaishnavi², MD. Abdul Muqet³, R. Ram Charan⁴,
V. Hussain⁵**

Professor, Dept. of Electrical & Electronics Engineering,

Christu Jyothi Institute of Technology & Science, Jangaon, Telangana, India¹

UG Student, Dept. of Electrical & Electronics Engineering,

Christu Jyothi Institute of Technology & Science, Jangaon, Telangana, India²⁻⁵

Abstract: Industrial facilities require continuous lighting for safe and efficient operations. Traditional lighting systems usually rely on manual switches or fixed schedules, which often leads to unnecessary energy consumption and inefficient lighting utilization. To overcome these limitations, an IoT-powered adaptive lighting system can be implemented.

The proposed system uses sensors such as occupancy sensors and ambient light sensors to detect human presence and natural lighting conditions. Based on this real-time data, a microcontroller automatically adjusts the brightness of industrial LED lights. The system also enables remote monitoring and control through IoT platforms and cloud services.

This approach significantly reduces energy consumption, improves safety, and enhances operational efficiency in industrial environments. Additionally, the system supports data analytics and centralized monitoring, making it suitable for smart industrial facilities.

Keywords: IoT, Adaptive Lighting, Industrial Automation, Energy Efficiency, Sensors, Smart Lighting.

I. INTRODUCTION

In recent years, industries have been focusing on improving energy efficiency, automation, and safety within their facilities. Lighting systems are one of the major contributors to electricity consumption in industrial environments.

Traditional lighting systems operate based on fixed schedules or manual switching mechanisms. These systems cannot adapt to changes in occupancy or environmental conditions, resulting in inefficient energy usage.

The Internet of Things (IoT) enables smart devices to communicate and exchange data through interconnected networks. By integrating IoT technologies with lighting systems, it becomes possible to create intelligent lighting solutions capable of monitoring environmental conditions and making automated decisions.

An IoT-powered adaptive lighting system uses sensors to detect occupancy and ambient light levels. Based on these inputs, a microcontroller adjusts the brightness of LED lights dynamically. This ensures that lighting is provided only when required and at optimal intensity levels.

The system can also transmit real-time data to cloud platforms, enabling remote monitoring, analytics, and centralized control. Such intelligent lighting systems support industrial automation and contribute to sustainable energy management.

II. LITERATURE SURVEY

1. Several research works and existing technologies have explored intelligent lighting systems and IoT-based automation.
2. Traditional industrial lighting systems mainly use fluorescent lamps, high-intensity discharge lamps, or simple LED lighting controlled by manual switches or timers. Although these systems are simple to implement, they lack adaptability and consume excessive electrical energy.

3. Researchers have introduced occupancy sensor-based lighting systems using sensors such as PIR and ultrasonic sensors to detect motion and switch lights ON or OFF automatically. These systems help reduce energy consumption in unused areas.
4. Another approach is the use of ambient light sensors such as LDR sensors, which measure the natural light level in the environment. When sufficient daylight is available, the artificial lighting intensity can be reduced.
5. Modern smart lighting solutions integrate IoT platforms and wireless communication technologies such as ZigBee, Wi-Fi, and LoRa to enable remote monitoring and automation. However, many commercial smart lighting platforms are designed mainly for office or residential environments and are not fully optimized for large industrial facilities.
6. Hybrid IoT-Edge computing systems have also been proposed, where real-time decisions are made locally by microcontrollers while the cloud performs data storage and analytics. This architecture provides faster response times and improved reliability.
7. These developments highlight the potential of IoT technology to improve industrial lighting systems by providing automation, energy optimization, and real-time monitoring.

III. PROBLEM STATEMENT

Industrial lighting plays a crucial role in ensuring worker safety, operational efficiency, and productivity. However, many industries still use traditional lighting systems that are inefficient and lack automation.

Existing lighting systems face several challenges such as:

- Excessive energy consumption due to continuous lighting
- Dependence on manual switching
- Lack of adaptability to environmental conditions
- Poor utilization of natural daylight
- High operational and maintenance costs

In many industrial facilities, lights remain switched ON even during non-working hours or when sufficient daylight is available. This leads to unnecessary energy wastage and increased electricity bills.

Therefore, there is a need for an intelligent lighting system that can automatically adjust lighting conditions based on real-time environmental data such as occupancy and ambient light levels.

The proposed solution aims to design an IoT-powered adaptive lighting system capable of optimizing lighting conditions, reducing energy consumption, and improving safety in industrial environments.

IV. BLOCKDIAGRAM

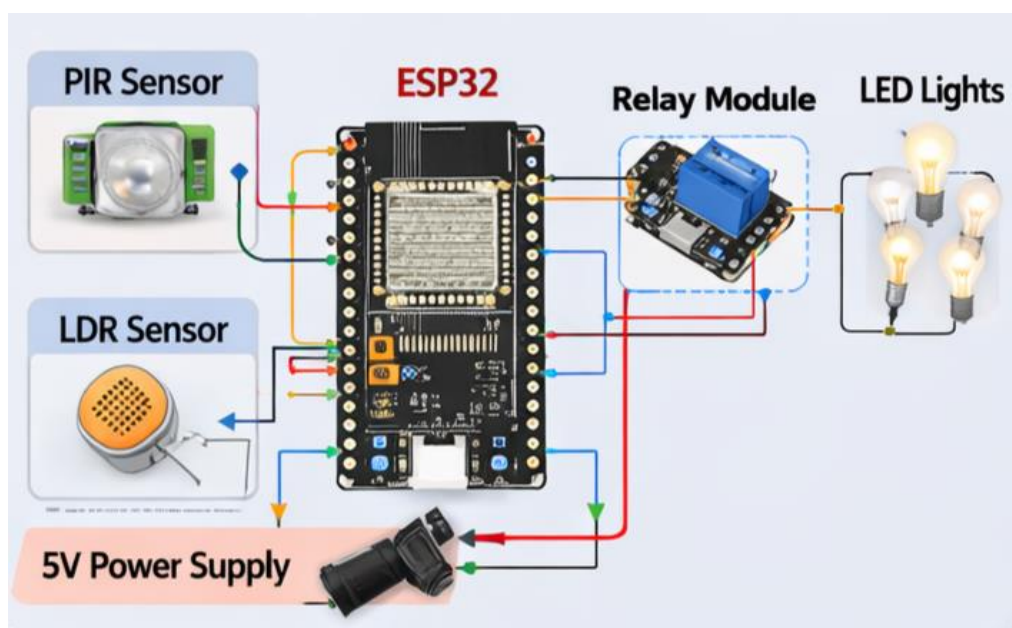


Fig.1: Block diagram

V. CIRCUIT DIAGRAM

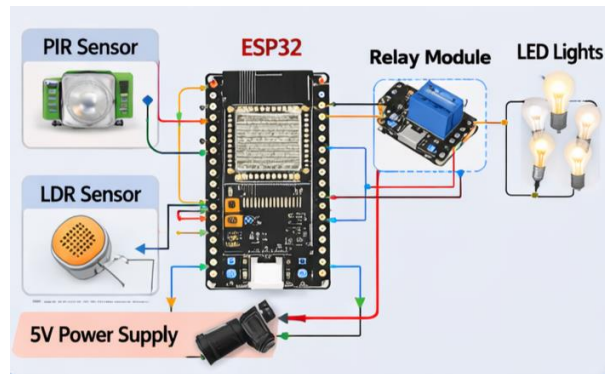


Fig.2: Circuit Diagram

The circuit diagram represents the electrical connections between various hardware components of the system.

The main components include:

1. ESP32 microcontroller
2. PIR occupancy sensor
3. LDR ambient light sensor
4. LED lighting unit
5. Relay modules
6. Power supply unit

The sensors are connected to the microcontroller through input pins, while LED lighting drivers are controlled through output pins using PWM signals.

VI. FLOW CHART

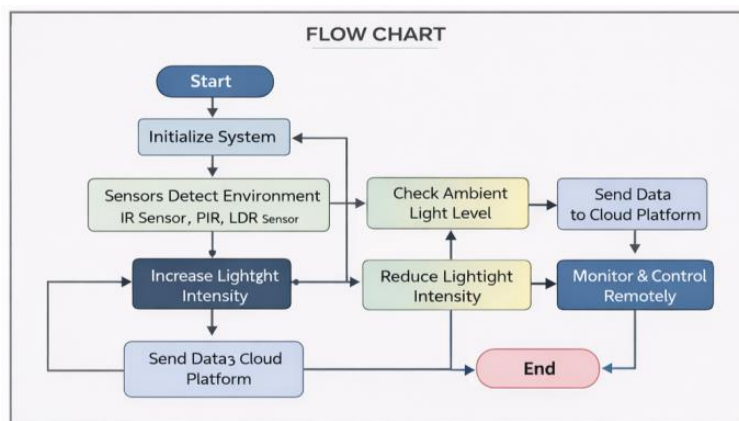


Fig.3: Flow Chart

VII. SYSTEM ARCHITECTURE OVERVIEW

The proposed system architecture for the IoT-Based Smart Industrial Lighting System is designed to monitor environmental conditions and automatically control lighting using sensors, a microcontroller, and a cloud platform. The system integrates IR sensors, LDR sensors, ESP32 microcontroller, relay modules, LED lights, and Blynk Cloud to achieve intelligent lighting control and remote monitoring.

The architecture consists of four major layers:

- Perception Layer
- Network Layer
- Processing Layer
- Application Layer

Each layer performs a specific function to ensure efficient data acquisition, processing, communication, and control.

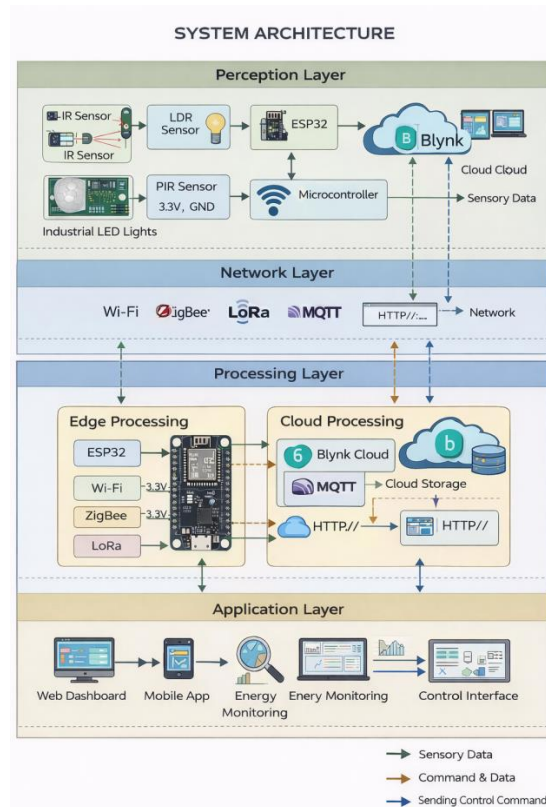


Fig.4: System Architecture

1. Perception Layer (Sensing Layer)

The Perception Layer is responsible for collecting real-time environmental data using sensors. It acts as the physical interface between the environment and the IoT system.

IR Sensor

The Infrared (IR) sensor is used to detect the presence or movement of objects or people within the monitored area. When an object interrupts the infrared beam, the sensor generates a signal indicating occupancy. This allows the system to automatically turn ON or adjust lighting when movement is detected.

LDR Sensor

The Light Dependent Resistor (LDR) measures the ambient light intensity in the environment. The resistance of the LDR changes depending on the amount of light falling on it.

- In bright conditions, resistance decreases.
- In dark conditions, resistance increases.

This information helps the system determine whether artificial lighting is required.

LED Lights

Industrial LED lights are used as the lighting load. These lights are controlled automatically based on sensor data.

Relay Module

The relay module acts as an electrical switch that allows the ESP32 microcontroller to control high-voltage LED lighting systems safely.

2. Network Layer (Communication Layer)

The Network Layer enables communication between the hardware system and the cloud platform.

Wi-Fi Communication

The ESP32 microcontroller has built-in Wi-Fi capabilities that allow it to connect to a local wireless network. Through Wi-Fi, sensor data is transmitted to the cloud and control commands are received from remote users.

Communication Protocol

The system communicates with the cloud using internet protocols such as:

- HTTP
- MQTT (used by Blynk for device communication)

This ensures reliable and real-time data transfer.

3. Processing Layer (Edge and Cloud Processing)

The Processing Layer is responsible for data analysis, decision-making, and system control.

Edge Processing (ESP32 Microcontroller)

The ESP32 performs local data processing by:

1. Reading sensor values from the IR and LDR sensors
2. Analyzing occupancy and light conditions
3. Making control decisions for LED lights
4. Sending sensor data to the cloud platform

Based on the sensor inputs, the ESP32 executes the following logic:

- If IR detects motion AND ambient light is low, turn ON the lights.
- If no motion is detected, turn OFF the lights.
- If sufficient natural light is present, reduce or turn OFF artificial lighting.

Cloud Processing (Blynk Cloud)

The Blynk Cloud platform is used for:

- Data storage
- Remote device monitoring
- Sending control commands
- Visualizing system data

Sensor readings and system status are continuously uploaded to the cloud where they can be accessed by the user.

4. Application Layer (User Interface Layer)

The Application Layer provides the interface between the user and the IoT system.

Blynk Mobile Application

The Blynk mobile app allows users to monitor and control the lighting system remotely. Through the app, users can:

- View real-time sensor readings
- Check lighting status
- Manually control lights
- Receive notifications
- Monitor energy usage

Dashboard Monitoring

The Blynk dashboard provides graphical visualization of system data such as:

- Light intensity levels
 - Occupancy detection status
 - LED ON/OFF status
 - System performance monitoring
- This improves user interaction and system management.

VIII. WORKING PRINCIPLE

The proposed IoT-Based Smart Lighting System operates by detecting human presence and ambient light intensity to automatically control industrial lighting. The system uses IR sensors and LDR sensors to collect environmental data, which is processed by the ESP32 microcontroller. Based on this data, the system controls LED lights through a relay module and sends monitoring information to the Blynk cloud platform.

Initially, when the system is powered ON, the ESP32 microcontroller initializes all connected components, including the IR sensor, LDR sensor, relay module, and Wi-Fi connection. The ESP32 connects to the internet through Wi-Fi and establishes communication with the Blynk Cloud platform for remote monitoring and control.

The IR sensor continuously monitors the environment to detect the presence of a person or object. When movement or an object is detected, the IR sensor sends a digital signal to the ESP32 microcontroller. At the same time, the LDR sensor measures the surrounding light intensity to determine whether the environment is bright or dark.

The ESP32 processes the sensor data and makes a decision based on predefined conditions:

- If motion is detected by the IR sensor and the ambient light level is low, the ESP32 activates the relay module, which turns ON the LED lights.
- If motion is detected but the ambient light is sufficient, the system may keep the lights OFF to save energy.
- If no motion is detected, the system automatically turns OFF the lights after a certain delay.

The relay module acts as an electronic switch that allows the low-voltage ESP32 to safely control high-voltage industrial LED lights.

Simultaneously, the ESP32 sends real-time data such as sensor readings, lighting status, and system activity to the Blynk Cloud platform using Wi-Fi communication. Through the Blynk mobile application, users can monitor the system remotely, view sensor data, and manually control the lights if required.

This intelligent operation ensures that lighting is used only when necessary, thereby reducing energy consumption, improving automation, and enhancing operational efficiency in industrial environments.

IX. RESULTS AND DISCUSSION

The proposed IoT-powered adaptive lighting system successfully demonstrated intelligent lighting control in industrial environments.

Key outcomes include:

- Automatic lighting adjustment based on occupancy and ambient light
- Significant reduction in energy consumption
- Improved worker safety due to optimal illumination
- Real-time monitoring through IoT dashboards
- Efficient utilization of natural daylight

The system also showed reliable communication between sensors, microcontroller, and cloud platforms, making it suitable for industrial automation.

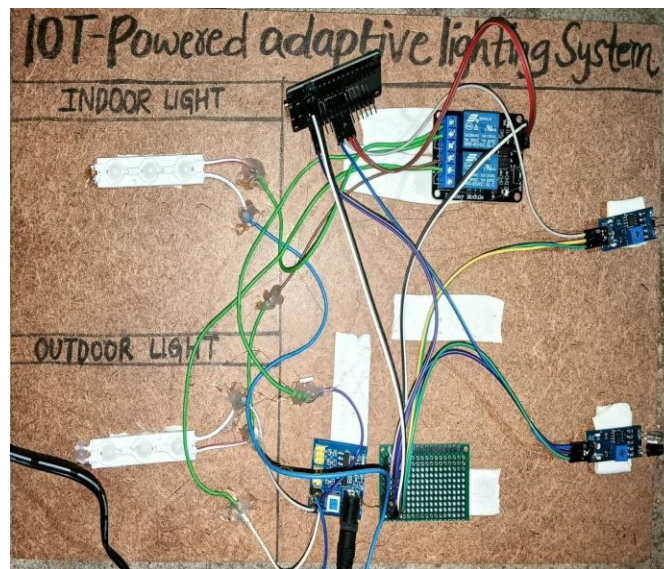


Fig.5: Top view of IoT-Powered Adaptive Lighting System for Industrial Facilities

X. CONCLUSION

The IoT-powered adaptive lighting system provides an efficient and intelligent solution for industrial lighting management.

By integrating sensors, microcontrollers, and IoT platforms, the system automatically adjusts lighting conditions based on environmental factors. This reduces energy consumption, improves safety, and enhances operational efficiency.

The proposed system also supports remote monitoring and data analytics, making it an important step toward smart industrial infrastructure and sustainable energy management.

XI. FUTURE WORK

The system can be further enhanced with advanced technologies such as:

✓ **AI and Machine Learning Integration**

To predict lighting requirements based on historical data.

✓ **Smart Energy Management**

Integration with renewable energy sources like solar power.

✓ **Advanced Sensor Networks**

Deployment of multiple sensors for better accuracy and coverage.

✓ **Integration with Industrial IoT Platforms**

For centralized facility management.

✓ **Predictive Maintenance**

Detect faults and maintenance requirements in lighting systems.

These enhancements will improve system intelligence and support large-scale industrial automation.

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