LoRa Based Green House Monitoring

And Control System Using IoT

A PROJECT REPORT

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BONAFIDE CERTIFICATE

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ABSTRACT

This project proposes a distributed, multi-span greenhouse monitoring and control system using LoRa communication and IoT technology to enhance agricultural productivity. Greenhouses provide a controlled environment for optimal plant growth while protecting crops from extreme weather conditions. The system continuously monitors key environmental factors such as temperature, moisture, illumination, pressure, and humidity. Automated control of devices like exhaust fans, sprinklers, and lighting systems is implemented based on predefined logic and climate conditions. Smart Alerts notify farmers of environmental stress or hardware failures through real-time app notifications. Additionally, Automated Contingency Protocols and Weather-Linked Automation ensure proactive responses to emergencies, minimizing risks. By integrating real-time monitoring and intelligent automation, this system optimizes crop growth, improves resource efficiency, and enhances resilience against environmental uncertainties.

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LIST OF ABBREVIATIONS

IoT	Internet of Things
ESP32	Espressif Systems Processor 32-bit
ADC	Analog to Digital Converter
PWM	Pulse Width Modulation
UART	Universal Asynchronous Receiver-Transmitter
SPI	Serial Peripheral Interface
I2C	Inter-Integrated Circuit
DHT22	Digital Humidity and Temperature Sensor
BMP280	Barometric Pressure Sensor
RH	Relative Humidity
LCD	Liquid Crystal Display
LDR	Light Dependent Resistor
MCU	Microcontroller Unit
LED	Light Emitting Diode
GPRS	General Packet Radio Service
MQTT	Message Queuing Telemetry Transport
HTTP	HyperText Transfer Protocol
IDE	Integrated Development Environment
LoRaWAN	Long Range Wide Area Network
IC	Integrated Circuit
PCB	Printed Circuit Board
DC	Direct Current
AC	Alternating Current
Wi-Fi	Wireless Fidelity
GSM	Global System for Mobile Communication

CHAPTER 1
INTRODUCTION

1.1 INTRODUCTION:

This project proposes a LoRa-Based Greenhouse Monitoring and Control System Using IoT to enhance the efficiency and productivity of greenhouse farming through an Environmental Management Automation process. In traditional greenhouse systems, manual monitoring and control are often inefficient and prone to human error. The proposed system addresses these challenges by automating the control of exhaust fans, sprinklers, lighting, and heating systems based on real-time sensor data such as temperature, humidity, illumination, soil moisture, and atmospheric pressure.

To further optimize crop health and yield, the system integrates a Fertilizer Recommendation Module within the web application. This feature analyzes real-time soil and environmental data to suggest appropriate fertilizers for different crop stages, promoting resource-efficient and targeted agricultural practices. Additionally, Smart Alerts notify farmers of environmental anomalies or equipment failures, while Automated Contingency Protocols respond to emergencies such as water pump or heater malfunctions. Weather-Linked Automation adjusts greenhouse parameters based on predictive weather data. The use of LoRa technology ensures low-power, long-range wireless communication, making the system scalable, cost-effective, and suitable for remote agricultural settings.

1.2 OBJECTIVE OF THE PROJECT:

The primary objective of this project is to design and implement a LoRa-Based Greenhouse Monitoring and Control System Using IoT that enables real-time environmental monitoring and intelligent control of greenhouse parameters.

The system aims to automate devices such as exhaust fans, sprinklers, and lighting based on sensor data including temperature, humidity, soil moisture, illumination, and atmospheric pressure. It also incorporates Smart Alerts and Automated Contingency Protocols to ensure system reliability and prevent crop loss during emergencies. Furthermore, a Fertilizer Recommendation Feature is integrated into the web application to provide data-driven suggestions for optimized crop growth. The project seeks to enhance crop yield, reduce manual intervention, and promote precision agriculture through affordable, scalable technology.

1.3 PROBLEM DEFINITION:

Traditional greenhouse farming relies on manual monitoring, making it inefficient and prone to errors. Factors like temperature, humidity, illumination, and soil moisture must be regulated to prevent crop loss. Existing automation systems often depend on cloud processing, causing delays. This project proposes a LoRa-based IoT system for real-time monitoring, automated control, smart alerts, and weather-adaptive automation to enhance efficiency and productivity.

1.4 PROPOSED METHOD:

This project utilizes a LoRa-based IoT system to provide real-time monitoring and automated control of greenhouse conditions. Multiple sensors continuously measure temperature, humidity, soil moisture, illumination, and atmospheric pressure, transmitting data to a central ESP32/Arduino-based controller via LoRa communication. The collected data is analyzed to regulate exhaust fans, sprinklers, water pumps, and lighting according to predefined thresholds or machine learning-based predictions.

To enhance reliability, Smart Alerts notify farmers via mobile applications about environmental stress, equipment malfunctions, or system failures. Automated Contingency Protocols are implemented to handle emergency conditions, such as sudden temperature spikes or irrigation failures, by activating backup devices. Additionally, Weather-Linked Automation integrates real-time weather forecasts to proactively adjust greenhouse conditions. This scalable, energy-efficient, and cost-effective system ensures improved agricultural productivity while minimizing manual intervention and resource wastage

1.5 DOMAIN BACKGROUND

Greenhouse farming is a controlled agricultural practice that enhances crop growth by regulating environmental conditions such as temperature, humidity, soil moisture, and light exposure. Traditional methods require manual intervention, which can be inefficient and labor-intensive. The integration of IoT, LoRa communication, and automation in greenhouse management enables real-time monitoring, data-driven decision-making, and remote control, significantly improving productivity, efficiency, and sustainability.

Advantages and Innovations:

The project's distinctive features and benefits include:

- Real-Time Monitoring: Continuously tracks environmental parameters like temperature, humidity, and soil moisture.
- Automated Control: Regulates fans, sprinklers, and lighting based on real-time data, reducing manual effort.
- Smart Alerts: Notifies farmers instantly about environmental stress or equipment failures.
- Energy & Resource Efficiency: Optimizes water and electricity usage through intelligent automation.
- Scalability & Cost-Effectiveness: Uses LoRa for long-range, low-power communication, ideal for large farms.

- Weather Adaptability: Adjusts greenhouse conditions based on real-time weather forecasts to prevent crop damage.

Innovation

- LoRa-Based IoT System: Ensures long-range, low-power communication for efficient data transmission.
- Automated Contingency Protocols: Activates backup systems during emergencies like temperature spikes or equipment failures.
- Weather-Linked Automation: Adjusts environmental parameters based on real-time weather predictions.
- Edge Computing Integration: Enables local decision-making without relying on cloud processing, improving response time.

1.6 OVERVIEW:

This project proposes a LoRa-Based Greenhouse Monitoring and Control System Using IoT to optimize crop growth through real-time environmental monitoring and automation. Sensors track temperature, humidity, soil moisture, illumination, and pressure, while LoRa technology enables long-range, low-power data transmission. Automated control of fans, sprinklers, and lighting ensures ideal conditions. Smart Alerts notify farmers of environmental stress or failures, while Automated Contingency Protocols and Weather-Linked Automation enhance system resilience. This scalable, energy-efficient solution improves productivity, minimizes manual intervention, and ensures sustainable greenhouse management through intelligent automation.

CHAPTER 2

LITERATURE REVIEW

[01] Singh, R. K., Aernouts, M., De Meyer, M., Weyn, M., & Berkvens, R. (2020). Leveraging LoRa-WAN Technology for Precision Agriculture in Greenhouses. Sensors, 20(1827).

This research focuses on deploying a LoRaWAN-based wireless sensor network for precision agriculture in greenhouses. The study identifies challenges in greenhouse monitoring and proposes solutions, such as improved sensor enclosure designs. The results highlight the importance of environmental monitoring and power-efficient network deployment in precision agriculture.

[02] Banu, Mohammadi, N., Channamma, & M. (2022). Monitor and Control Sensors in the Greenhouse Using LoRa Technology. 45th Series Student Project Programme (SPP) – 2021-22.

This student project explores the use of LoRa technology to monitor and control greenhouse sensors remotely. The system integrates temperature, humidity, and fire detection sensors, which transmit data to a cloud platform via LoRa gateways. The research highlights LoRa’s low energy consumption and long-range communication benefits for smart agriculture.

[03] Liu, D., Xin, C., Chongwei, H., & Liangliang, J. Intelligent Monitoring Technology. Agriculture System (2015). Greenhouse Using IoT 2015 International Conference on Intelligent Transportation, Big Data & Smart City.

This paper presents an IoT-based greenhouse monitoring system that uses various environmental sensors for data collection. The system leverages real-time data analysis to optimize greenhouse conditions, ensuring better crop yield and resource efficiency. The study emphasizes IoT's role in enhancing agricultural sustainability.

[04] Mezouari, A., Elkarch, H., Haoul, C., Dahou, H., & Elgouri, R. (2023). LoRa WAN-based Intelligent Multi- Greenhouse Monitoring and Control. E3S Web of Conferences, Volume 469, ICEGC'2023.

This research focuses on a multi-greenhouse monitoring system using IoT and LoRaWAN technology. The system tracks climate variables like humidity, temperature, and brightness, helping farmers make data-driven decisions. The approach improves efficiency by reducing manual intervention and optimizing greenhouse management.

[05] Glória, A., Cardoso, J., & Sebastião, P. (2021). Sustainable Irrigation System for Farming Supported by Machine Learning and Real-Time Sensor Data. Sensors, 21(9), 3079.

This study presents an automatic irrigation control system that integrates wireless sensor networks, machine learning algorithms, and mobile applications. The system utilizes real-time sensor data to predict optimal irrigation schedules, with the Random Forest model achieving an accuracy of 84.6%. The implementation demonstrated up to 60% water savings, highlighting its potential as a sustainable solution for modern agriculture. The approach emphasizes the role of IoT and AI in enhancing resource efficiency and decision-making in farming practices.

[06] Liu, J., & Yao, W. (2019). Intelligent Agriculture System Based on LoRa and Qt Technology. Proceedings of the 2019 Chinese Control and Decision Conference (CCDC), 8833476.

This paper proposes an intelligent agriculture system that employs LoRa technology for wireless communication and Qt-based software for monitoring environmental parameters in greenhouses. The system includes sensors for temperature, humidity, and light intensity, which transmit data via a LoRa network to a central monitoring unit. The integration of these technologies enhances real-time monitoring capabilities and reduces labor costs associated with manual data collection, contributing to more efficient greenhouse management.

[07] Wang, Q. H., Bian, L. J., & Pang, Y. J. (2011). Design of the Temperature Monitoring System Based on ZigBee Wireless Sensor Network.

This study presents a greenhouse monitoring system utilizing ZigBee wireless sensor networks to measure environmental parameters such as temperature and humidity. The system automates the control of devices like fans and sprinklers based on sensor data. While effective for small-scale applications, the limited range and node-handling capacity of ZigBee make it less suitable for large greenhouses. The authors suggest that for improved scalability and outdoor usability, protocols like LoRa with longer communication ranges and lower power consumption are more appropriate for greenhouse automation in expansive agricultural settings.

[08] Sunandini, M., Hema Sree, K., & Deepiga, R. (2023). Smart Soil Fertilizer Monitoring and Crop Recommendation System by Using IoT and Machine Learning Technology. International Journal of Engineering Research & Technology (IJERT), 12(6).

This paper presents a fertilizer advisory system that leverages real-time soil parameters and crop datasets to suggest appropriate fertilizer types and quantities. It utilizes a machine learning model integrated with IoT sensors and displays recommendations via a web platform. The study showcased improved crop yield and efficient fertilizer use, reducing costs and environmental impact.

While it didn't include greenhouse automation, its modular design and cloud-based interface support integration into larger agricultural monitoring systems, like the one proposed in this project.

[09] Sujin, J. S., Murugan, R., Nagarjun, M., & Praveen Akash, K. (2021). IoT-Based Greenhouse Monitoring and Controlling System. Journal of Physics: Conference Series, 1916(1), 012062.

This research introduces an IoT-based greenhouse management system that automates environmental control using sensors and Wi-Fi-enabled microcontrollers. The system adjusts lighting, temperature, and irrigation in real-time while providing remote access through cloud platforms. It significantly improves agricultural productivity and conserves resources. However, the dependence on stable internet connectivity limits its reliability in rural areas. The paper recommends adopting long-range communication technologies such as LoRa for areas with limited network infrastructure, making it more applicable to rural agricultural environments.

[10] Singh, K., & Hota, M. K. (2022). Design of Low-Cost IoT Enabled Greenhouse Control System for Precision Agricultural Research Application. IOP Conference Series: Materials Science and Engineering.

This paper presents a budget-friendly IoT-based greenhouse system using sensors to monitor temperature, humidity, light, and soil moisture. The system automates control of fans, foggers, heaters, and irrigation. Designed for research applications, it enables precise microclimate regulation, supporting studies on plant growth and resource optimization in harsh environments.

CHAPTER 3

PROJECT DESCRIPTION

3.1 PROPOSED SYSTEM

The proposed system is a LoRa-Based Greenhouse Monitoring and Control System Using IoT, designed to enhance greenhouse farming through real-time environmental monitoring and automated climate regulation. The system employs sensors to continuously measure temperature, humidity, soil moisture, illumination, and atmospheric pressure, ensuring optimal growing conditions. The collected data is transmitted via LoRa communication to an ESP32/Arduino-based central controller, which processes the information and adjusts exhaust fans, sprinklers, water pumps, and lighting systems based on predefined thresholds or machine learning algorithms. This enables precise, automated control of greenhouse conditions while reducing manual intervention and improving efficiency.

To ensure system reliability, Smart Alerts notify farmers of environmental anomalies or hardware failures, enabling timely intervention. Additionally, Automated Contingency Protocols activate backup mechanisms during emergencies, such as sudden temperature fluctuations or irrigation failures, preventing crop damage. Weather-Linked Automation further enhances adaptability by adjusting greenhouse conditions based on real-time weather forecasts. Leveraging LoRa technology, this system ensures low-power, long-range communication, making it highly scalable for multi-span greenhouses. This innovative, cost-effective, and energy-efficient solution improves productivity while ensuring sustainable and intelligent greenhouse management.

3.2 BLOCK DIAGRAM

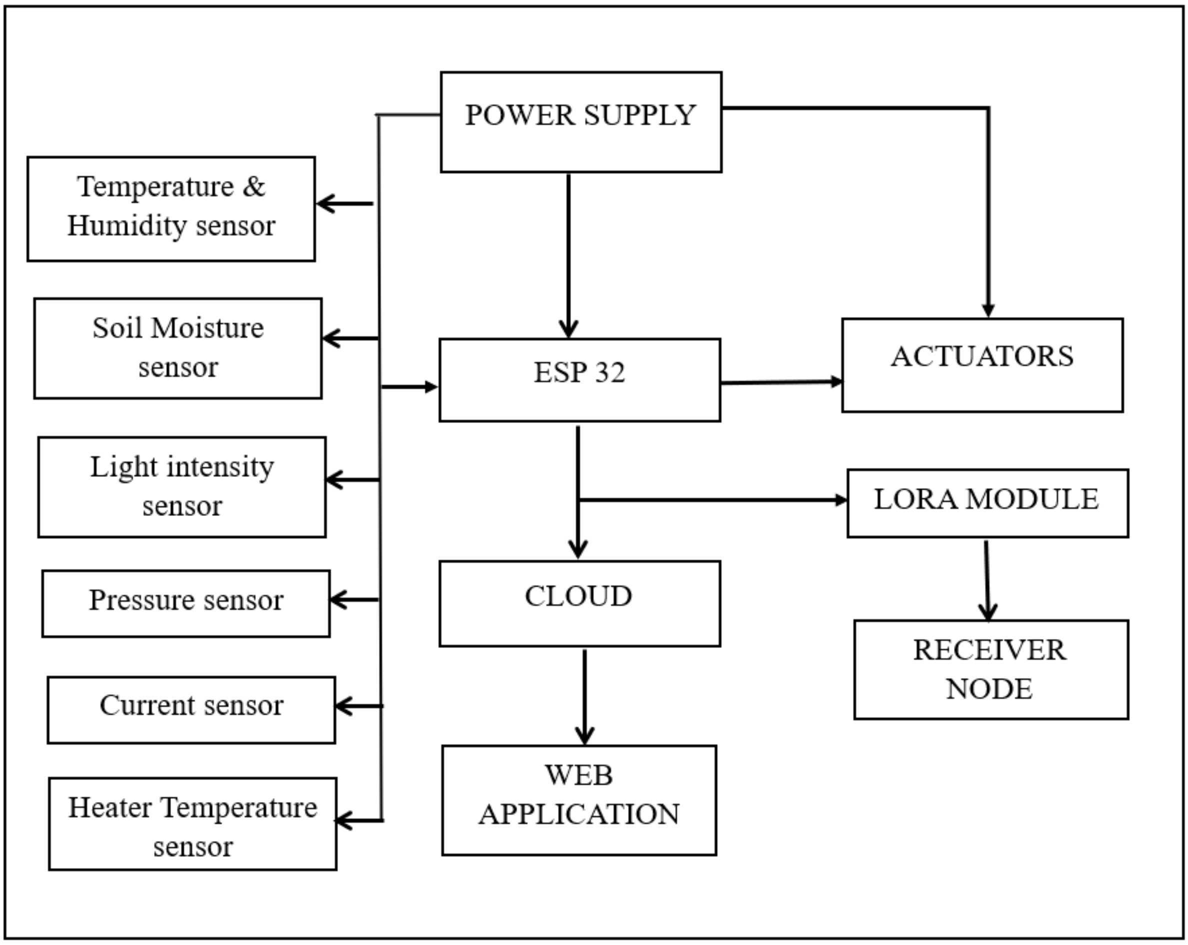


Fig. 3.2 Block Diagram

3.2.1 BLOCK DESCRIPTION:

The block diagram outlines the architecture of a LoRa-Based Greenhouse Monitoring and Control System Using IoT, designed to automate and optimize the agricultural environment in real-time. The system is powered by a stable power supply that supports all components, including the ESP32 microcontroller, sensors, actuators, and the LoRa module. Sensors play a crucial role by continuously collecting data on environmental parameters such as temperature, humidity, soil moisture, light intensity, and atmospheric pressure. This real-time data is sent to the ESP32 microcontroller, which serves as the system's central processing unit. Based on predefined conditions or intelligent logic, the microcontroller processes the input and triggers actuators such as exhaust fans, water pumps, sprinklers, and lighting systems. These actuators respond by adjusting greenhouse conditions automatically, ensuring optimal growth settings while minimizing manual effort.

The processed environmental data is also transmitted via the LoRa module, which enables long-range, low-power wireless communication between the sensor node and the cloud server. This ensures seamless remote monitoring and scalability, even in multi-span or isolated greenhouse setups. The cloud server functions as a centralized platform for storing sensor data, tracking historical trends, and enabling predictive analytics through machine learning models. On the user end, a dedicated web application serves as an intuitive interface that allows farmers to remotely monitor greenhouse metrics, configure control parameters, and receive smart alerts in case of environmental stress or equipment malfunctions. The integration of cloud services and a web-based dashboard enhances the system's reliability, accessibility, and intelligence, thereby supporting data-driven decision-making and improving agricultural productivity.

3.3 METHODOLOGY

This project implements a LoRa-Based Greenhouse Monitoring and Control System Using IoT to automate and optimize greenhouse farming. The system architecture comprises two main units: the transmission (sensor) node and the receiver node. The transmission node features an ESP32 microcontroller connected to various sensors that measure key environmental parameters such as temperature, humidity, soil moisture, light intensity, and atmospheric pressure. These sensors continuously collect real-time data, which is processed by the ESP32. Based on this data, control decisions are made locally and sent via a LoRa module to the receiver node over long-range communication.

The receiver node, equipped with another LoRa module, receives the transmitted data and displays the real-time values through an LCD screen. This data is also sent to a cloud-based server, which is linked to a custom-built web application. Farmers can access this web dashboard to monitor greenhouse conditions remotely, configure threshold values, and receive automated alerts for environmental stress or equipment failure. Actuators such as exhaust fans, sprinklers, pumps, and lighting systems are controlled either automatically based on preset logic or manually through the web interface, ensuring timely adjustments for optimal crop growth.

An innovative addition to this system is the fertilizer recommendation feature integrated into the web application. By analyzing real-time soil moisture data and other parameters, the system can recommend the right type and quantity of fertilizer based on crop requirements and predefined agronomic models. This intelligent addition enhances precision farming and resource efficiency. The entire system ensures scalability, low power consumption, and real-time responsiveness through LoRa communication. Overall, the methodology supports intelligent, automated, and efficient greenhouse management while reducing manual labor and increasing productivity in a sustainable manner.

3.4 HARDWARE REQUIREMENT

3.4.1 NODEMCU (ESP32)

The ESP32 is a powerful and versatile microcontroller used as the central control unit in this greenhouse monitoring and automation system. It is a dual-core, 32-bit processor developed by Espressif Systems, offering high performance with ultra-low power consumption—making it ideal for IoT-based agricultural applications. The ESP32 supports both Wi-Fi and Bluetooth connectivity, although in this project, it primarily interfaces with sensors and actuators while communicating data to the LoRa module for long-range transmission.

The board comes equipped with multiple General-Purpose Input/Output (GPIO) pins, analog-to-digital converters (ADCs), pulse-width modulation (PWM) capabilities, and UART, SPI, and I2C communication protocols, enabling seamless integration with various sensors such as temperature, humidity, soil moisture, light intensity, and atmospheric pressure sensors. It receives real-time sensor data, processes it based on predefined logic, and controls actuators accordingly.

Additionally, the ESP32 ensures reliable communication with the LoRa module via its serial interface, sending data to the receiver node or cloud server. The onboard memory and processing power allow for implementing intelligent decision-making algorithms and contingency protocols for automated environmental regulation. Its compact design, energy efficiency, and robust functionality make the ESP32 a critical component in achieving real-time monitoring and automation in smart greenhouse systems.

Fig. 3.4.1 Node MCU

3.4.2 SENSORS

The LoRa-Based Greenhouse Monitoring and Control System Using IoT incorporates multiple sensors to monitor critical environmental parameters that influence plant growth. These sensors ensure real-time data collection and automated decision-making, helping to maintain optimal greenhouse conditions. Below is a detailed description of each sensor used in the project:

3.4.2.1 TEMPERATURE AND HUMIDITY SENSOR (DHT22)

The DHT22 sensor is used to measure air temperature and humidity inside the greenhouse. It features high accuracy and stability, making it suitable for agricultural applications. The sensor consists of a thermistor for temperature measurement and a capacitive humidity sensor to detect moisture levels in the air. The collected data is processed by the microcontroller to regulate cooling fans, ventilation systems, or heaters when necessary.

- Operating Voltage: 3.5V to 5.5V
- Operating current: 0.3mA (measuring) 60uA (standby)
- Output: Serial data
- Temperature Range: -40°C to 80°C

- Humidity Range: 0% to 100%
- Resolution: Temperature and Humidity both are 16-bit
- Accuracy: ±0.5°C and ±1%

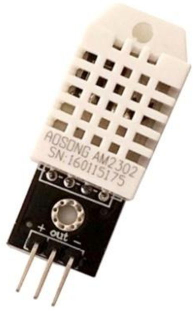


Fig. 3.4.2.1 DHT22 Temperature and Humidity sensor

3.4.2.2 SOIL MOISTURE SENSOR

The soil moisture sensor helps in measuring the water content in the soil to determine the need for irrigation. It operates on the principle of measuring the resistance or capacitance of the soil, where drier soil offers more resistance, and moist soil has lower resistance. The sensor ensures automated irrigation by activating the water pump when soil moisture levels drop below a predefined threshold.

- **Operating Voltage:** 3.3V – 5V
- **Moisture Detection Range:** 0% to 100%
- **Output Type:** Analog and Digital

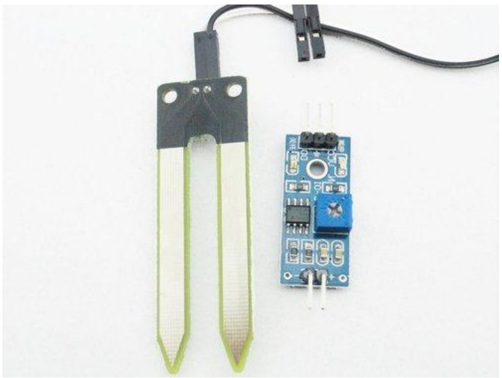


Fig. 3.4.2.2 Soil Moisture Sensor

3.4.2.3 LIGHT INTENSITY SENSOR (BH1750)

The light-dependent resistor (LDR) or BH1750 digital light sensor is used to measure ambient light intensity inside the greenhouse. This sensor ensures that plants receive adequate light for photosynthesis by controlling LED grow lights or adjusting shading mechanisms. It is particularly useful in automated lighting systems that respond to natural daylight conditions.

- Light Intensity Range: 1 – 65535 lux
- Operating Voltage: 3.3V – 5V
- Output Type: Digital (I^2C interface)

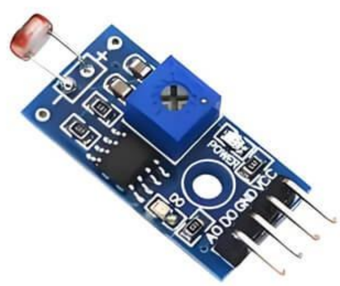


Fig. 3.4.2.3 Light Intensity Sensor (BH1750)

3.4.2.4 ATMOSPHERIC PRESSURE SENSOR (BMP280)

The BMP280 sensor measures barometric pressure, which plays a key role in predicting weather changes inside the greenhouse. Changes in atmospheric pressure can affect temperature, humidity, and ventilation. The BMP280 variant includes additional humidity and temperature sensing, making it a comprehensive environmental monitoring sensor.

- Pressure Range: 300 – 1100 hPa
- Temperature Range: -40°C to +85°C
- Humidity Range (BME280 only): 0% to 100% RH
- Accuracy: ±1 hPa (pressure), ±0.5°C (temperature)

Fig. 3.4.2.4 Atmospheric Pressure sensor(BMP280)

3.4.2.5 CURRENT SENSOR

A current sensor is used in the LoRa-Based Greenhouse Monitoring and Control System to measure the electrical current consumption of various components, including water pumps, fans, lighting systems, and other actuators. Monitoring current usage helps in energy management, fault detection, and system efficiency optimization.

In this project, the ACS712 Hall Effect Current Sensor is used due to its high accuracy, efficiency, and ease of integration with microcontrollers like ESP32/ESP8266. It operates on the Hall Effect principle, where the sensor measures the magnetic field generated by the flowing current and converts it into a proportional voltage output.

- Operating Voltage: 5V
- Current Measurement Range: ±5A, ±20A, or ±30A (based on model)
- Sensitivity: 66mV/A (for ±30A model)
- Output Type: Analog voltage signal
- Response Time: < 5µs

Working Principle

- The ACS712 sensor is connected in series with the load to measure the current flow.
- It generates an analog voltage output proportional to the detected current, which is then fed into the ESP32's ADC (Analog-to-Digital Converter).
- The microcontroller processes this data to monitor power usage and identify potential faults.

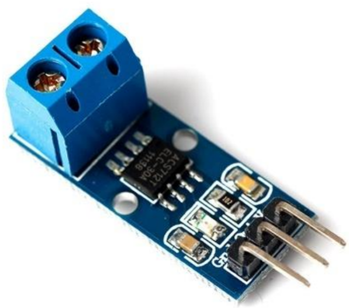


Fig. 3.4.2.5 Current sensor

3.4.2.6 HEATER TEMPERATURE SENSOR

A heater temperature sensor is used in the LoRa-Based Greenhouse Monitoring and Control System to monitor and regulate the temperature of heating elements inside the greenhouse. This ensures that the system maintains an optimal temperature for plant growth, especially in colder conditions. The sensor helps prevent overheating, energy wastage, and equipment failure, thereby improving efficiency and safety.

For this project, the DS18B20 Digital Temperature Sensor is commonly used due to its high accuracy, wide temperature range, and digital output.

- Operating Voltage: 3.3V – 5V
- Temperature Range: -55°C to +125°C
- Accuracy: ±0.5°C (in the range of -10°C to +85°C)
- Output Type: Digital (1-Wire communication)
- Waterproof Variant: Available for direct heater surface monitoring

Working Principle

- The DS18B20 sensor is placed near or attached to the heating system to measure temperature changes.
- It sends real-time temperature data to the ESP32 microcontroller via a 1-Wire digital interface.
- If the temperature falls below a preset threshold, the microcontroller activates the heater to maintain warmth.
- If overheating is detected, the system can turn off the heater or trigger an alert for safety measures.

Fig. 3.4.2.6 Heater Temperature Sensor

3.4.3 ACTUATORS

In the LoRa-Based Greenhouse Monitoring and Control System Using IoT, actuators serve as the key components responsible for executing control actions based on sensor data. These actuators help maintain optimal temperature, humidity, soil moisture, air circulation, and lighting conditions, ensuring the greenhouse remains suitable for plant growth. The integration of these actuators with ESP32 microcontroller, LoRa communication, and cloud-based monitoring enables automated responses to environmental changes, reducing manual labour and improving efficiency. Below is a detailed explanation of the actuators used in the project.

3.4.3.1 WATER PUMP FOR AUTOMATED IRRIGATION

The water pump is responsible for supplying water to the plants based on real-time soil moisture levels. It is controlled using a relay switch, which is triggered by data from the soil moisture sensor.

Working Mechanism:

- The soil moisture sensor detects moisture levels in the soil and sends the data to the ESP32.

- If the moisture level falls below the threshold (e.g., below 30%), the microcontroller activates the relay module, switching on the water pump.
- The pump supplies water through drip irrigation pipes or sprinklers until the soil reaches optimal moisture levels.
- Once the soil moisture is restored, the system turns off the pump automatically.

Key Benefits:

- Prevents overwatering or underwatering, ensuring optimal soil moisture.
- Reduces water wastage by irrigating only when necessary.
- Supports precision agriculture by delivering the right amount of water to each plant.

Fig. 3.4.3.1 Water Pump

3.4.3.2 HEATER BULB FOR TEMPERATURE REGULATION

A heater is integrated into the system to maintain a stable temperature during cold conditions. The heater is controlled using a relay module, which is activated when the temperature sensor detects a drop below the optimal range.

Working Mechanism:

- The DS18B20 temperature sensor continuously monitors the ambient temperature inside the greenhouse.
- If the temperature falls below a preset threshold (e.g., 15°C), the ESP32 activates the relay module, turning on the heater.
- The heater runs until the temperature stabilizes, after which the system automatically shuts it off.

Key Benefits:

- Protects plants from cold stress and frost damage.
- Automates greenhouse temperature control without manual intervention.
- Prevents excessive power consumption by operating only when required.

3.4.3.3 EXHAUST FANS FOR VENTILATION CONTROL

Exhaust fans are used to regulate air circulation and remove excess heat or humidity from the greenhouse. When the temperature or humidity sensors detect a value above the predefined threshold, the ESP32 microcontroller sends a control signal to activate the fans.

Working Mechanism:

- The DHT22 temperature and humidity sensor continuously monitors ambient conditions.
- If the temperature exceeds the set limit (e.g., above 30°C), the microcontroller triggers the relay module to switch on the exhaust fans.
- The fans work by pulling out warm, humid air and drawing in cooler air, stabilizing the environment.

- Once the temperature returns to normal, the system automatically turns off the fans to conserve energy.

Key Benefits:

- Prevents heat stress on plants.
- Reduces excessive humidity that could lead to mold or fungal growth.
- Ensures continuous air circulation, improving CO_2 distribution for photosynthesis.

Fig. 3.4.3.3 Exhaust Fans for Ventilation Control

3.4.3.4 LED GROW LIGHTS FOR SUPPLEMENTAL LIGHTING

LED grow lights are used to provide artificial lighting when natural sunlight is insufficient, ensuring plants receive adequate illumination for photosynthesis.

Working Mechanism:

- The light intensity sensor (LDR or BH1750) measures ambient light levels.
- If light intensity falls below the required level (e.g., at night or during cloudy weather), the ESP32 activates the LED lights using a relay switch.
- Once sufficient light is available, the system turns off the lights to save energy.

Key Benefits:

- Ensures plants receive consistent lighting for optimal growth.
- Energy-efficient operation using low-power LEDs.
- Supports photoperiod-dependent crops, which require specific light cycles for growth.

Fig. 3.4.3.4 LED Grow Lights

3.4.4 LoRa MODULE

The LoRa (Long Range) module is used in this project for wireless communication between sensors, actuators, and the cloud. It enables long-range, low-power data transmission, ensuring real-time monitoring and control of greenhouse conditions. LoRa technology allows environmental data, such as temperature, humidity, and soil moisture, to be sent to a LoRa gateway, which relays it to a cloud-based dashboard. This system facilitates remote control of actuators like water pumps, exhaust fans, and heaters, enhancing greenhouse automation with minimal power consumption and reduced operational costs.

The LoRa module plays a crucial role in establishing a low-power, long-range communication network for greenhouse monitoring. It enables seamless wireless data exchange between ESP32 microcontrollers and a central LoRa gateway, which then transmits data to a cloud-based dashboard for remote access. The system continuously collects environmental parameters, such as temperature, humidity, soil moisture, and light intensity, and transmits them via the LoRaWAN (LoRa Wide Area Network) protocol. Based on this data, automated control actions are triggered, such as activating exhaust fans, switching on irrigation pumps, or adjusting lighting. LoRa's low power consumption, wide coverage range, and interference resistance make it an ideal choice for smart greenhouse applications, ensuring reliable monitoring, efficient automation, and real-time alerts for farmers.

Fig. 3.4.4 LoRa Module

3.4.5 ARDUINO UNO

In the LoRa-Based Greenhouse Monitoring and Control System Using IoT, the Arduino Uno is used exclusively in the transmitter node to facilitate data communication between the ESP32 and the LoRa module. It serves as an interface to process and transmit sensor data efficiently, ensuring reliable long-range communication for monitoring and automation.

Role of Arduino Uno in the Transmitter Node

The transmitter node is responsible for collecting real-time environmental data from various sensors, including temperature, humidity, soil moisture, and light intensity. The ESP32 microcontroller gathers this data and sends it to the Arduino Uno, which processes the information and forwards it to the LoRa module for transmission. The key functions of the Arduino Uno in this system include:

- Receiving and processing sensor data from the ESP32.
- Formatting the data for structured transmission via LoRa communication.
- Sending the processed data to the LoRa module, ensuring long-range wireless communication.
- Displaying real-time sensor readings on an LCD screen for local monitoring at the transmitter node.
- Ensuring stable and efficient data transfer to prevent packet loss or transmission errors.

Why Arduino Uno is Used in the Transmitter Node

- Reliable Data Handling: Ensures accurate sensor data processing before transmission.
- Efficient Communication: Acts as a bridge between ESP32 and LoRa, enabling seamless data transmission.
- Low Power Consumption: Operates efficiently in an IoT-based system with minimal energy requirements.
- Ease of Integration: Compatible with multiple sensors and communication modules.

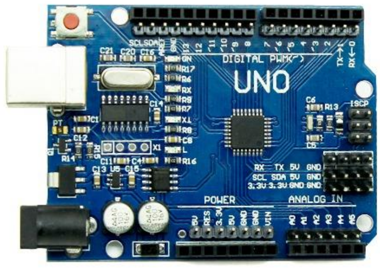


Fig. 3.4.5 Arduino uno

3.4.6 BUZZER

The buzzer is an essential component in the LoRa-Based Greenhouse Monitoring and Control System Using IoT, primarily used for audio alerts and notifications. It serves as an immediate warning system to notify farmers about critical environmental conditions or system malfunctions. The integration of the buzzer enhances the overall reliability of the system by ensuring that potential hazards, such as extreme temperature variations, high humidity levels, water pump failures, or sensor malfunctions, are promptly addressed.

Working Mechanism

The ESP32 microcontroller controls the buzzer, activating it based on predefined conditions detected by the system's sensors. When an anomaly is identified, such as high temperature, low soil moisture, or hardware failure, the microcontroller triggers the buzzer to emit an alert sound. The buzzer can operate in different modes, such as continuous or intermittent beeping, depending on the severity of the alert. Additionally, it can work alongside LoRa-based alerts, ensuring that both local and remote notifications are sent to the farmer for immediate action.

Applications in the Project

- Critical Condition Alerts: Notifies users of extreme environmental conditions, such as excessive heat or low humidity, requiring immediate intervention.
- Hardware Malfunction Alerts: Alerts in case of sensor failure, pump malfunction, or system faults.
- Automation Confirmation: Provides an audible signal when an actuator, such as the water pump, heater, or exhaust fan, is activated or deactivated.
- Security and Unauthorized Access Alerts: Can be used to notify unauthorized entry into the greenhouse.

Fig. 3.4.6 Buzzer

3.4.7 RELAY

The relay module is a crucial component in the LoRa-Based Greenhouse Monitoring and Control System Using IoT, serving as an electromechanical switch that controls high-power devices, such as water pumps, heaters, exhaust fans, and grow lights. Since microcontrollers like ESP32 operate at low voltage and cannot directly handle high-power loads, relays act as an interface to safely switch these devices on or off based on real-time sensor data.

Working Mechanism

A relay consists of a coil, contacts, and a switching mechanism. When the ESP32 microcontroller sends a low-power control signal, the relay coil is energized, creating a magnetic field that closes or opens the circuit connected to high-power greenhouse equipment. This mechanism allows automated control of environmental conditions based on real-time sensor readings. For example, if the temperature exceeds the threshold, the relay activates the exhaust fan or heater to maintain optimal conditions.

Applications in the Project

- Irrigation System Control: Activates or deactivates the water pump based on soil moisture levels.
- Temperature Regulation: Turns on/off heaters and exhaust fans depending on ambient temperature.
- Lighting Automation: Controls LED grow lights based on ambient light conditions.
- Ventilation System Operation: Regulates motorized windows or vents to ensure proper airflow.

Fig. 3.4.7 Relay

3.4.8 LIQUID CRYSTAL DISPLAY

A Liquid Crystal Display is an electronically-modulated optical device shaped into a thin, flat panel made up of any number of colour or monochrome pixels filled with liquid crystals and arrayed in front of a light source (backlight) or reflector. It is often utilized in battery-powered electronic devices because it uses very small amounts of electric power. Liquid Crystal Display has material, which continues the properties of both liquids and crystals. Rather than having a melting point, they have a temperature range within which the molecules are almost as mobile as they would be in a liquid, but are grouped together in an ordered from similar to a crystal. They are used in similar applications where Liquid Emitted Diodes are used. These applications are display of display of numeric and alphanumeric characters in dot matrix and segmental displays.

In the LoRa-Based Greenhouse Monitoring and Control System Using IoT, Liquid Crystal Displays (LCDs) are utilized in both the Transmitter Node and Receiver Node to provide real-time visual feedback of system status, sensor data, and control actions. LCDs play a crucial role in improving system usability by allowing farmers or operators to monitor critical greenhouse parameters locally, reducing the need for continuous mobile or cloud-based monitoring.

LCD in the Transmitter Node

The Transmitter Node is responsible for collecting environmental data from various sensors, such as temperature, humidity, soil moisture, and light intensity, before transmitting it via LoRa communication. The LCD in this node is used to:

- Display real-time sensor readings, allowing users to check the greenhouse conditions before transmission.
- Show transmission status, confirming whether the data is successfully sent to the receiver node.

- Indicate system alerts or errors, such as sensor malfunctions or communication failures.

Typically, a 16x2 LCD or OLED display is used, interfaced with an ESP32 or Arduino, to ensure clear and real-time data visualization.

LCD in the Receiver Node

The Receiver Node is responsible for receiving transmitted data via LoRa and displaying it for monitoring or control actions. The LCD in this node serves the following functions:

- Displays received environmental parameters, allowing farmers to monitor greenhouse conditions in real time.
- Shows control actions taken, such as whether a heater, fan, or water pump has been activated.
- Indicates alerts or emergency conditions, helping users take immediate action if necessary.
- Provides system status updates, confirming successful communication between transmitter and receiver.

Advantages of Using LCD in the Project

- Real-Time Monitoring: Displays instant feedback on environmental conditions and system actions.
- User-Friendly Interface: Allows local monitoring without needing a cloud or mobile application.
- Low Power Consumption: Efficient operation, suitable for IoT-based applications.
- Improved System Debugging: Helps diagnose sensor or communication issues quickly.

Fig. 3.4.8 LIQUID CRYSTAL DISPLAY

3.4.9 POWER SUPPLY

The power supply unit is a critical component in the LoRa-Based Greenhouse Monitoring and Control System Using IoT, ensuring stable and efficient power distribution to all electronic components. The system operates on multiple voltage levels (12V, 5V, and 3.3V) to support various modules, including the ESP32 microcontroller, sensors, actuators, and LoRa module. A well-regulated power supply enhances system reliability and efficiency, preventing voltage fluctuations that could damage components.

Power Supply Components and Working.

1. **12V Adapter**
    - The system is powered by a 12V DC adapter, which serves as the primary power source.
    - This 12V supply is essential for driving high-power components such as relays, exhaust fans, water pumps, and heaters.
2. **Voltage Regulator (7805 - 5V Output)**
    - The 7805 Voltage regulator is used to step down the 12V DC input to a stable 5V output.
    - It powers sensors (DHT22), LCD display, and Arduino Uno (in the transmitter node).

- Capacitors (100µF and 1000µF) are used to stabilize the voltage output and filter noise.

3. **3.3V Supply for ESP32 and LoRa Module**
    - The ESP32 microcontroller and LoRa (RA-02) module operate at 3.3V, which is derived from the onboard voltage regulator of the ESP32.
    - This ensures efficient power management for wireless communication and sensor processing.
4. **Powering Sensors and Actuators**
    - Low-power sensors such as temperature (DHT22), pressure (BMP280), and soil moisture sensors operate on either 3.3V or 5V, ensuring compatibility with the ESP32.
    - Relays (12V) control high-power devices like water pumps, exhaust fans, and heaters. The relays are driven by transistors (BC547, BC337), ensuring safe switching between low-voltage control signals and high-power loads.

3.5 SOFTWARE REQUIREMENT

3.5.1 ARDUINO IDE

The Arduino Integrated Development Environment (IDE) is a cross-platform application (for Windows, macOS, Linux) that is written in functions from C and C++. It is used to write and upload programs to Arduino compatible boards, but also, with the help of third-party cores, other vendor development boards. The source code for the IDE is released under the GNU General Public License, version 2. The Arduino IDE supports the languages C and C++ using special rules of code structuring. The Arduino IDE supplies a software library from the Wiring project, which provides many common input and output procedures.

User-written code only requires two basic functions, for starting the sketch and the main program loop, that are compiled and linked with a program stub main () into an executable cyclic executive program with the GNU toolchain, also included with the IDE distribution

Fig. 3.5.1 Arduino IDE

3.5.2 LORA COMMUNICATION AND DATA TRANSMISSION

LoRa communication is implemented using the LoRaWAN protocol, which enables long-range, low-power wireless data transmission. The ESP32 and Arduino Uno communicate with the LoRa module (Ra-02) via SPI (Serial Peripheral Interface) or UART (Universal Asynchronous Receiver-Transmitter) to ensure stable data transfer. The transmitter node sends sensor data through the LoRa module, and the receiver node processes and displays it for local monitoring. This method ensures low-power, long-distance communication, making it ideal for agricultural applications where Wi-Fi or cellular networks may not be available.

3.5.3 WEB-BASED MONITORING AND CLOUD INTEGRATION

The system features a web-based dashboard for real-time monitoring and remote control of greenhouse conditions. The dashboard allows users to view sensor readings such as temperature, humidity, soil moisture, and light intensity. It is developed using HTML, CSS, JavaScript, and PHP, which provide an interactive interface and backend function. PHP scripts handle data requests, while a MySQL database stores sensor readings for historical analysis and performance tracking. The ESP32 sends data to the web server using HTTP requests or MQTT protocol, enabling seamless cloud integration.

3.5.4 DATA VISUALIZATION AND CONTROL

To enhance local monitoring, the system includes an LCD display (16x2) that shows real-time sensor values at both the transmitter and receiver nodes. The LCD display is programmed using the LiquidCrystal library in Arduino IDE, allowing clear and structured data presentation. The system also supports MQTT (Message Queuing Telemetry Transport) or HTTP protocols for transmitting data between the IoT devices and the web server. These protocols ensure low-latency data exchange, allowing users to receive instant notifications and alerts if critical greenhouse conditions are detected.

3.5.5 ADDITIONAL SOFTWARE TOOLS

The project can integrate ThingSpeak, a cloud-based IoT analytics platform, for data logging and visualization if additional cloud storage and analytics are required. Additionally, Python-based machine learning algorithms can be incorporated in future enhancements to predict environmental conditions and automate control decisions. This would enable the system to optimize greenhouse conditions based on historical data trends, further improving agricultural efficiency.

CHAPTER 4
RESULTS AND DISCUSSION

Transmission Node

The Transmission Node is responsible for collecting, processing, and transmitting environmental data to the receiver node. The ESP32 microcontroller gathers real-time data from sensors such as DHT22 (temperature & humidity), DS18B20 (temperature), BH1750 (light intensity), BMP280 (pressure), and soil moisture sensors.

Once collected, the ESP32 sends the data to the Arduino Uno, which processes and structures the readings before transmission. The LoRa module (Ra-02) then transmits the data over long distances to the receiver node, ensuring real-time monitoring. An LCD display at the transmission node shows live sensor values, allowing local monitoring of greenhouse conditions.

The power supply unit provides stable voltage using a 12V adapter and voltage regulators (7805 and 3.3V converters) to ensure reliable operation of all components. LoRa technology enables low-power, long-range communication, making the system ideal for agricultural environments with limited internet connectivity.

If critical environmental changes such as extreme temperatures or low soil moisture occur, the transmission node automatically triggers an alert via LoRa. This alert helps the receiver node take necessary control actions, such as activating fans, heaters, or irrigation systems.

By enabling automated data transmission, real-time alerts, and remote monitoring, the transmission node enhances greenhouse efficiency, minimizes manual intervention, and optimizes crop growth, making it a crucial part of the IoT-based automation system.

Hardware module is given below

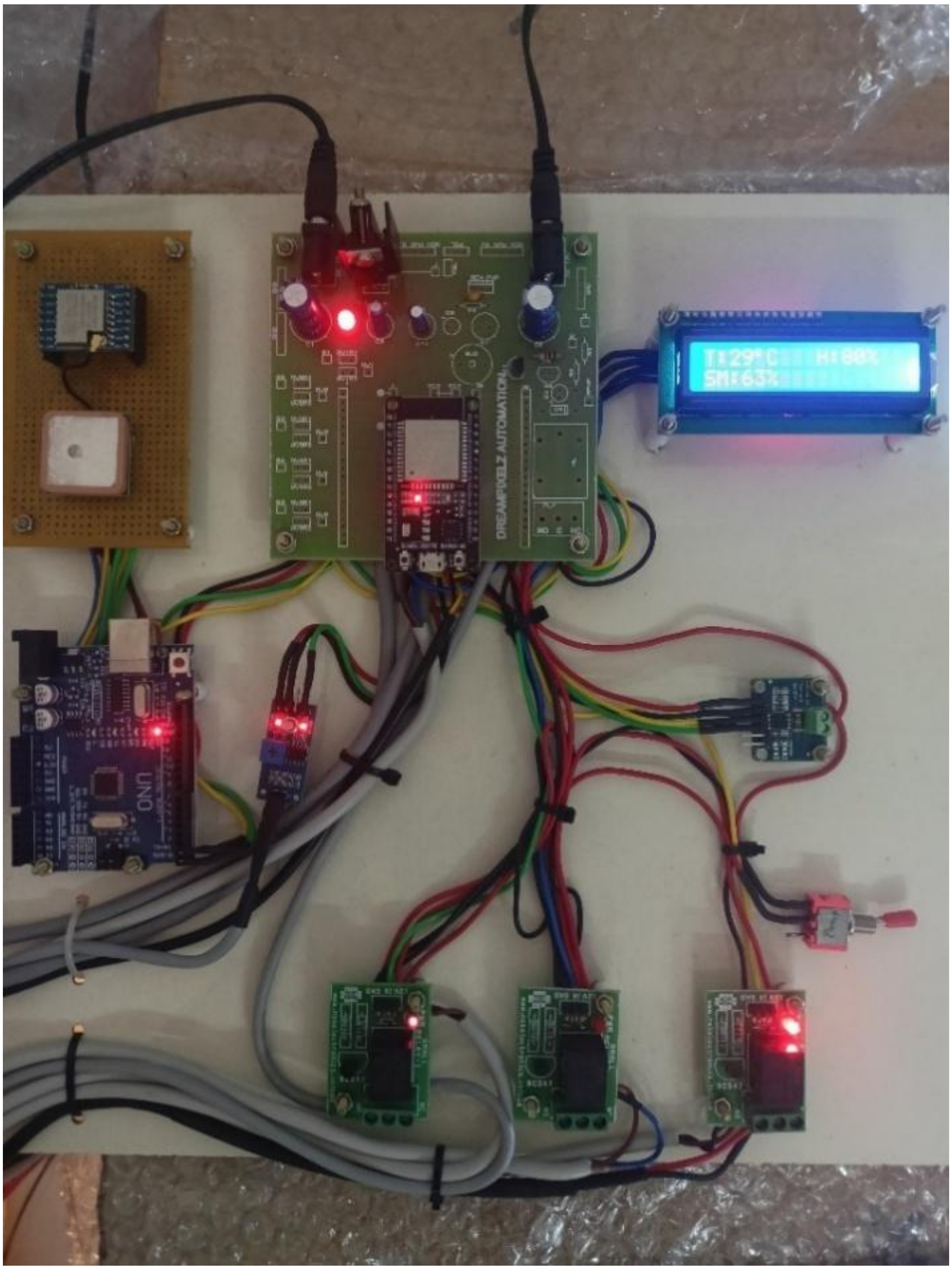


Fig 4.1 Transmission node

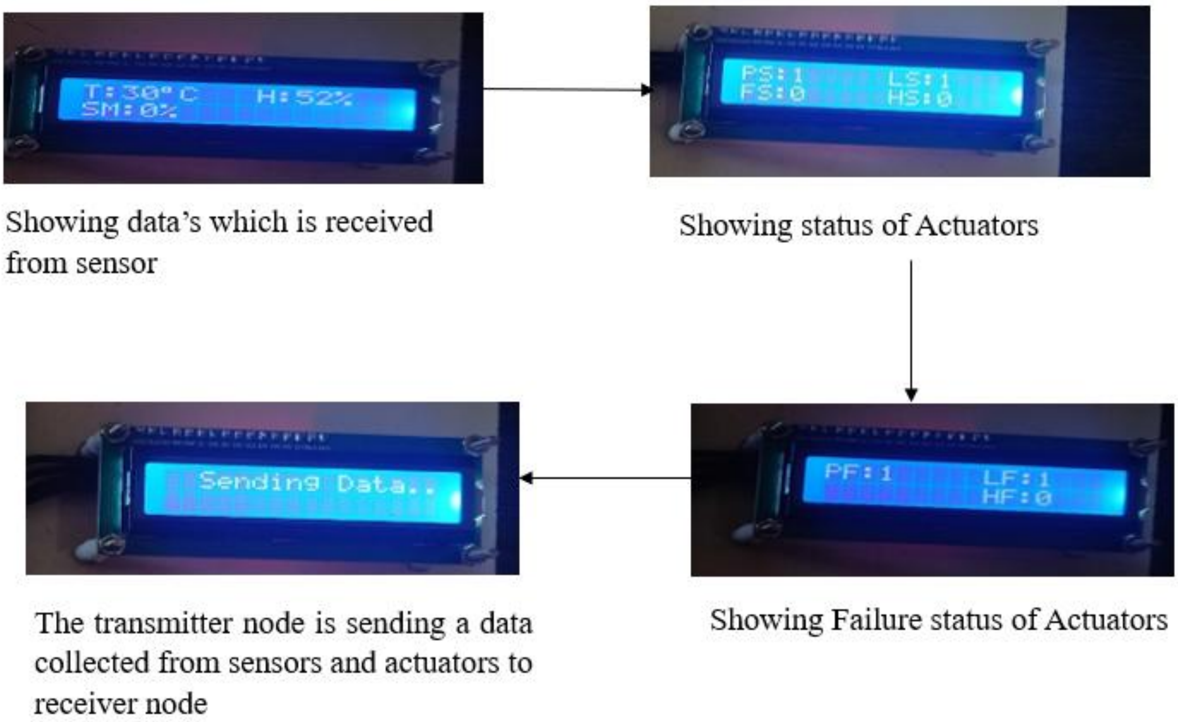


Fig 4.2 Result on Transmission module

Receiver Node

The Receiver Node is responsible for receiving environmental data from the Transmission Node and triggering appropriate control actions. The LoRa module (Ra-02) receives transmitted sensor data, including temperature, humidity, soil moisture, and light intensity, from the Transmission Node.

The ESP32 microcontroller processes the received data and determines necessary actions based on predefined thresholds. The LCD display at the receiver node provides real-time monitoring, showing live sensor readings for temperature, humidity, and soil moisture levels. If environmental parameters exceed or fall below set limits, the ESP32 automatically activates actuators such as fans, heaters, water pumps, or lights.

For example, if the temperature is too high, the system activates the exhaust fan to cool the greenhouse. If soil moisture drops, the water pump is turned on to irrigate the plants. The ESP32 also forwards processed data to a cloud-based dashboard, enabling remote monitoring and control via a web application.

The power supply unit, consisting of a 12V adapter and voltage regulators (7805 and 3.3V converters), ensures stable operation of all components. The system also generates alerts for critical conditions, notifying users through the web dashboard.

By enabling real-time monitoring, automated control, and remote access, the Receiver Node enhances greenhouse efficiency, reduces manual intervention, and optimizes resource utilization, making it a crucial part of the IoT-based greenhouse automation system.

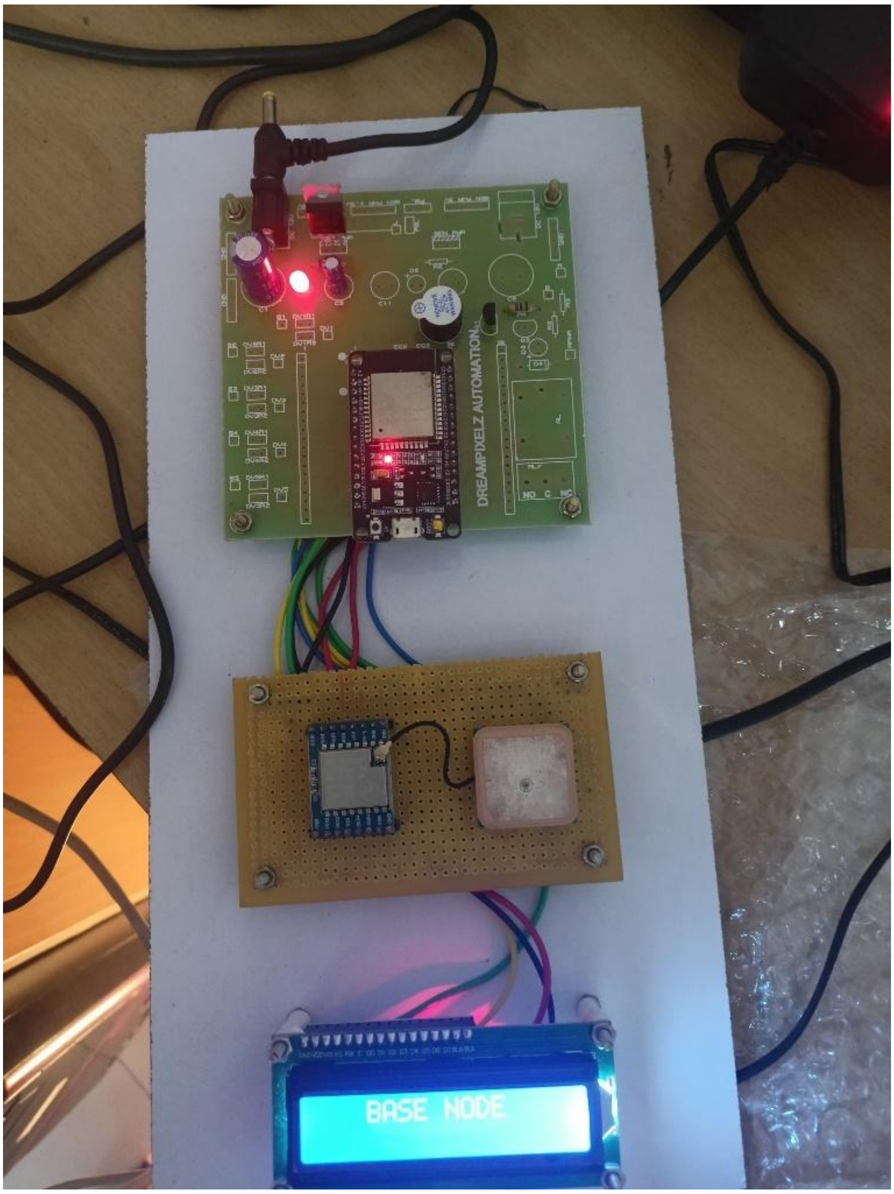


Fig 4.3 Receiver node

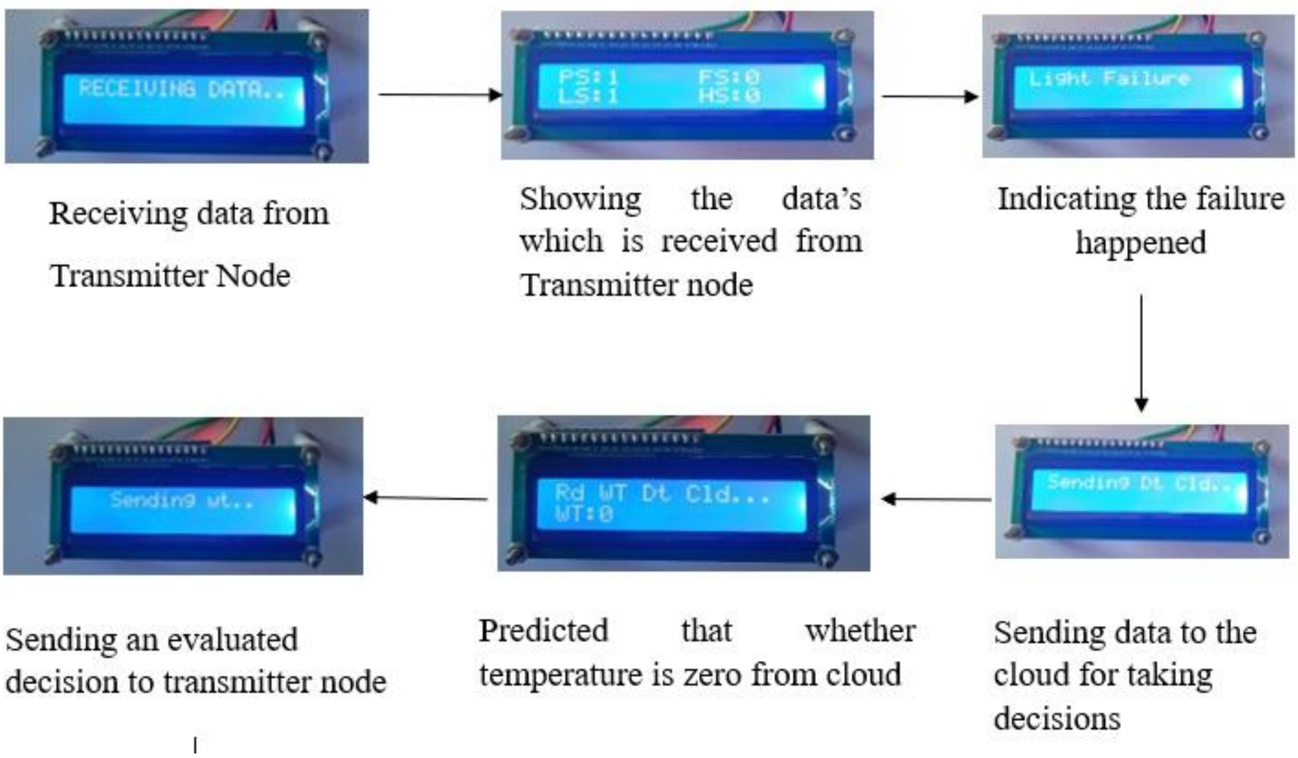


Fig 4.4 Result on Receiver module

T	TEMBERATURE
H	HUMIDITY
SM	SOILMOITURE
PH	PRESSURE
PS	PUMP STATUS
HS	HEATER STATUS
LS	LIGHT STATUS
FS	FAN STATUS
PF	PUMP FAILURE
HF	HEATER FAILURE
LF	LIGHT FAILURE
WT	WEATHER TEMPERATURE

TABLE RESULT ABBREVIATIONS

Web Application

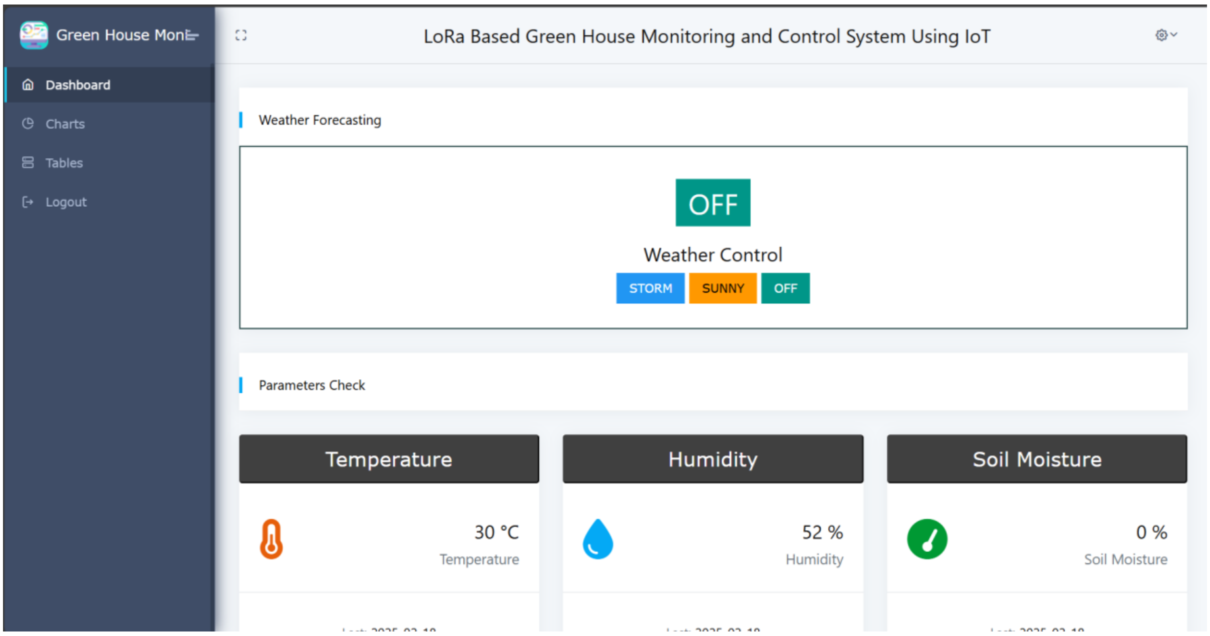


Fig 4.5(1) In Website field Monitoring

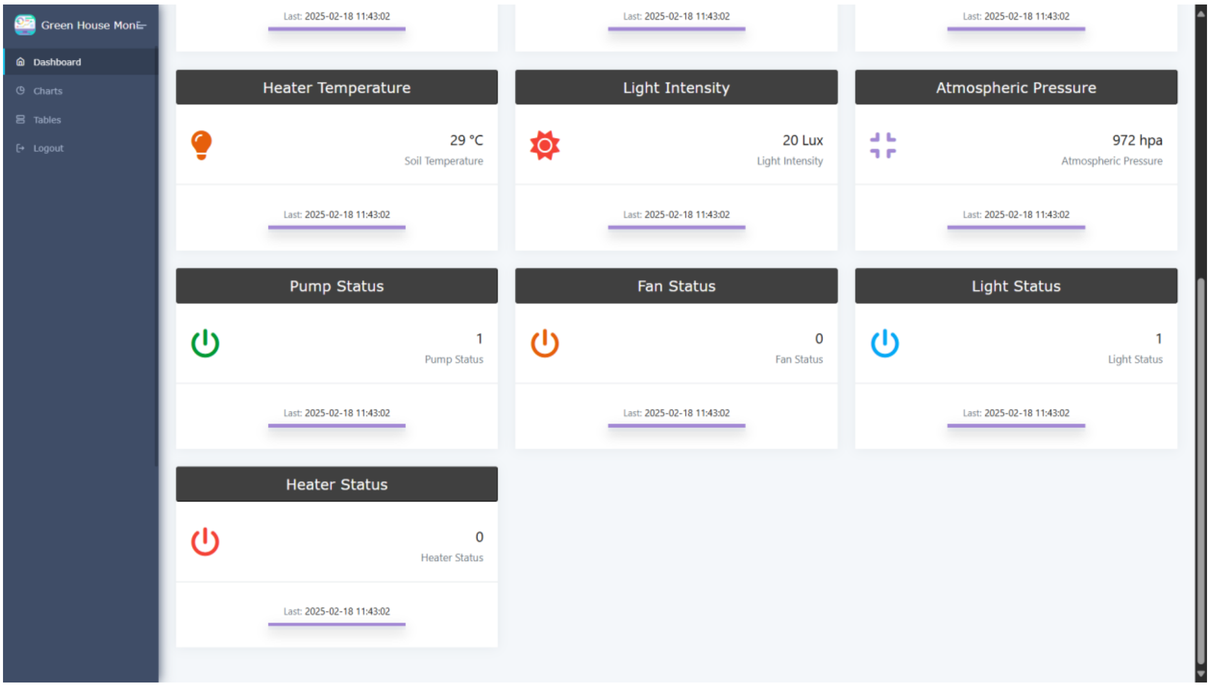


Fig 4.5(2) In Website field Monitoring

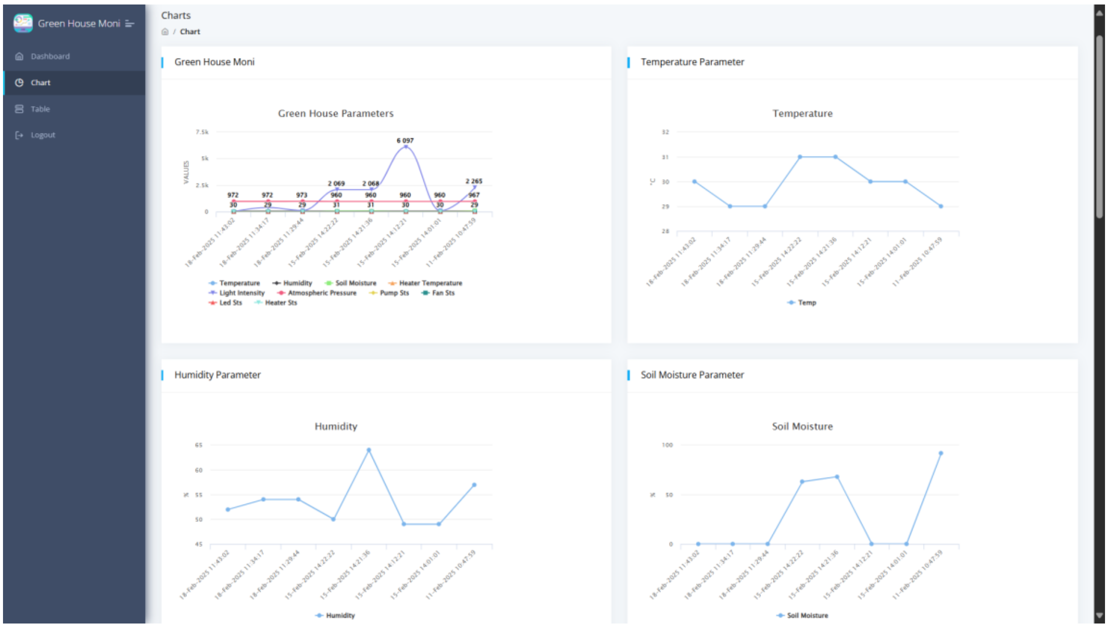
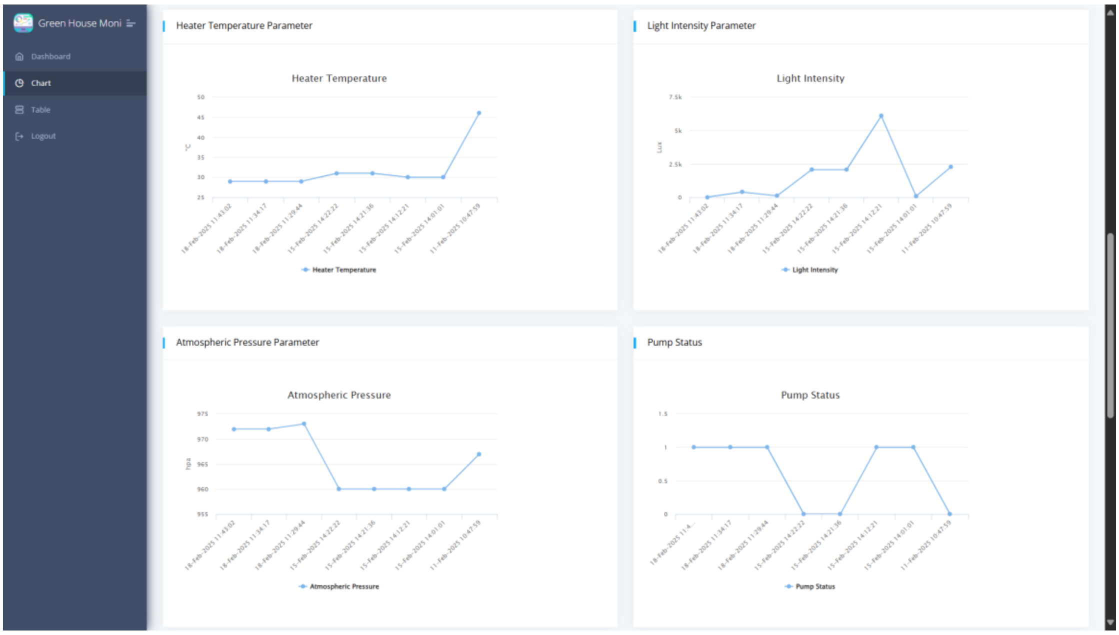


Fig 4.5(3) Field Monitored graphical chart



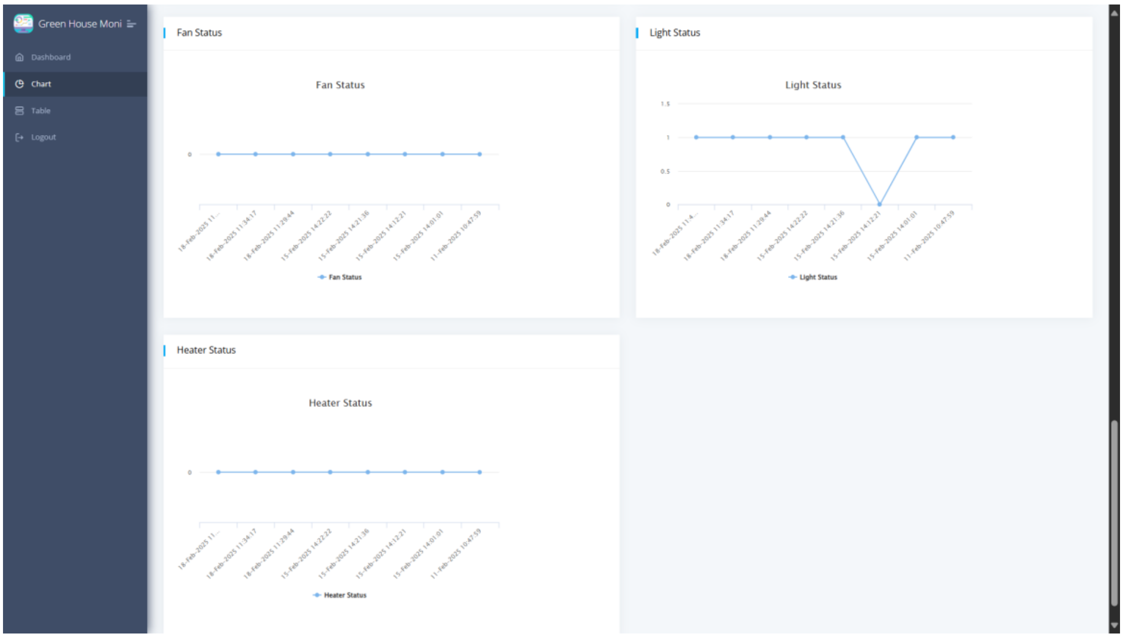
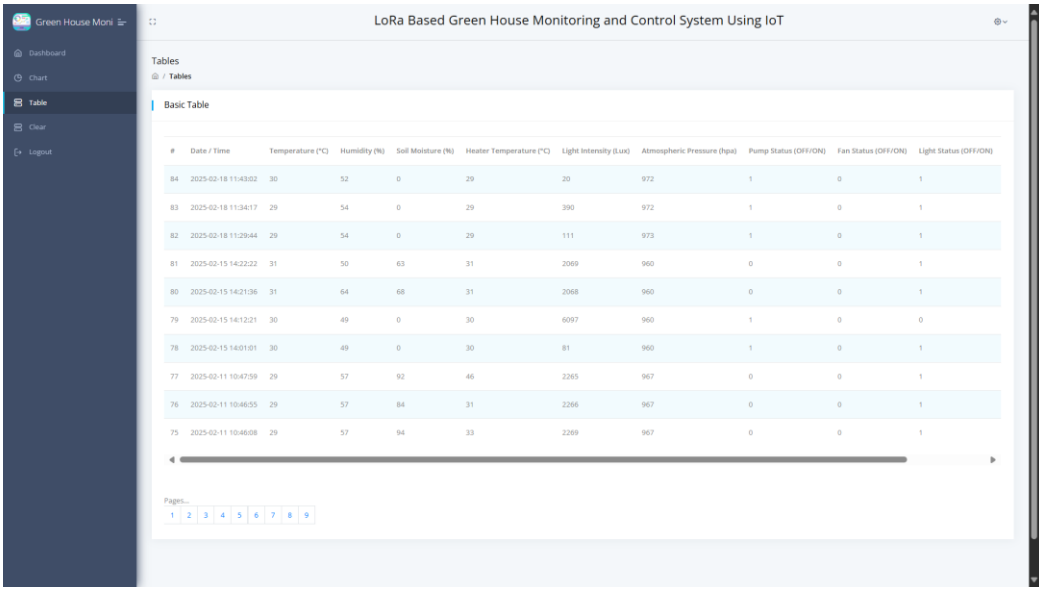


Fig 4.5(4) Field Monitored graphical chart



#	Date / Time	Temperature (°C)	Humidity (%)	Soil Moisture (%)	Heater Temperature (°C)	Light Intensity (Lux)	Atmospheric Pressure (hpa)	Pump Status (OFF/ON)	Fan Status (OFF/ON)	Light Status (OFF/ON)
84	2025-02-18 11:43:02	30	52	0	29	20	972	1	0	1
83	2025-02-18 11:34:17	29	54	0	29	390	972	1	0	1
82	2025-02-18 11:29:44	29	54	0	29	111	973	1	0	1
81	2025-02-15 14:22:22	31	50	63	31	2069	960	0	0	1
80	2025-02-15 14:21:36	31	64	68	31	2068	960	0	0	1
79	2025-02-15 14:12:21	30	49	0	30	6097	960	1	0	0
78	2025-02-15 14:01:01	30	49	0	30	81	960	1	0	1
77	2025-02-11 10:47:59	29	57	92	46	2265	967	0	0	1
76	2025-02-11 10:46:55	29	57	84	31	2266	967	0	0	1
75	2025-02-11 10:46:08	29	57	94	33	2269	967	0	0	1

Fig 4.5(5) Monitored value

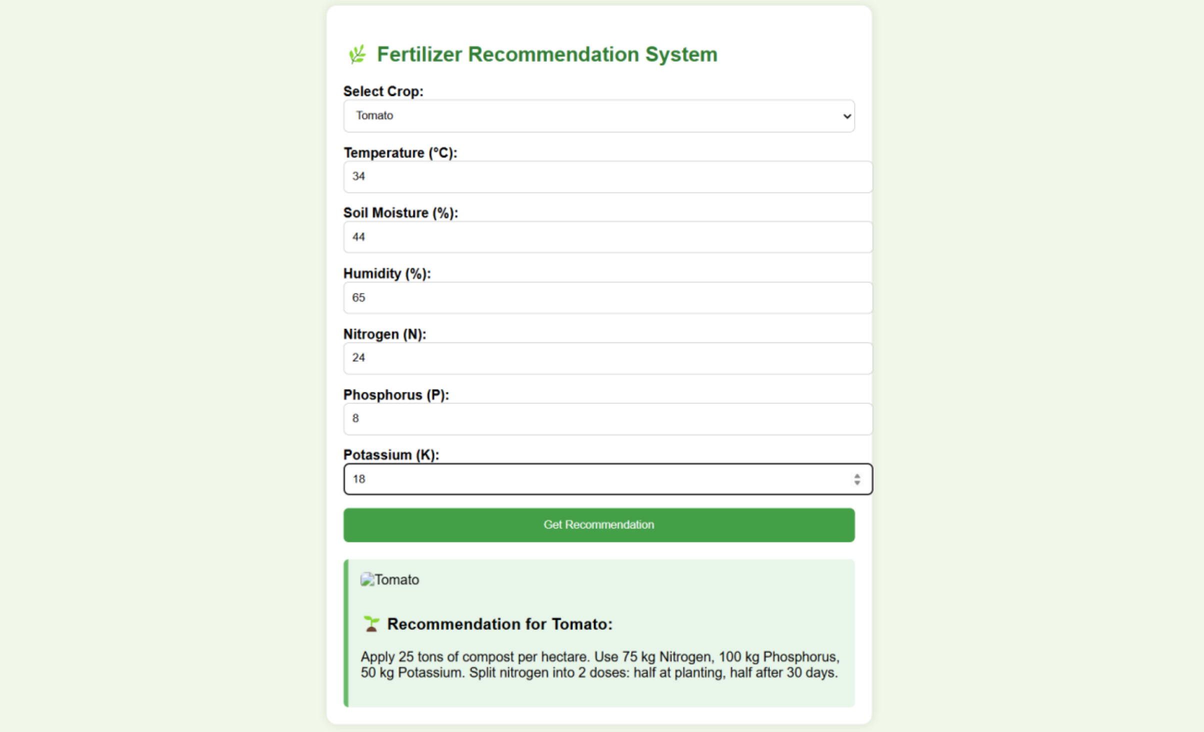


Fig 4.5(6) Fertilizer recommendation result

CHAPTER 5
CONCLUSION

The proposed LoRa-Based Greenhouse Monitoring and Control System Using IoT successfully demonstrates a smart, scalable, and energy-efficient solution for modern agriculture. By integrating environmental sensors with the ESP32 microcontroller and LoRa communication, the system ensures real-time monitoring and automated control of key greenhouse parameters such as temperature, humidity, soil moisture, light, and pressure. The incorporation of smart alerts and automated contingency protocols significantly reduces risks due to environmental fluctuations or system failures. A major advancement in this project is the addition of a web-based fertilizer recommendation feature, which guides farmers on optimal nutrient application based on real-time sensor data and predefined crop models. This not only improves yield but also promotes precision farming practices. The cloud-enabled web interface allows remote access and control, making the system highly user-friendly. Overall, the project promotes sustainability, improves productivity, and reduces manual intervention in greenhouse farming operations.

FUTURE SCOPE:

The LoRa-Based Greenhouse Monitoring and Control System Using IoT has significant potential for further advancements and scalability in smart agriculture. Integrating advanced data analytics will enable farmers to gain deeper insights into crop health and improve yield forecasting.

Further improvements can be made by implementing solar-powered IoT nodes, ensuring energy efficiency and sustainability in greenhouse operations. Edge computing can be integrated to process data locally, reducing reliance on cloud-based processing and improving real-time response. Additionally, expanding the LoRa network to support multiple greenhouses can enhance scalability, allowing for centralized monitoring of large agricultural areas.

Future developments can also incorporate automated pest detection systems, weather-based irrigation scheduling, and blockchain-based data security for enhanced reliability. By adopting these advancements, the system can contribute to precision farming, resource conservation, and higher agricultural productivity in the future.

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