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Smart Agri Pump Protection and Monitoring System

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Abstract: *The Smart Agri Pump Protection and Monitoring System is an IoT-based solution designed to improve the safety, reliability, and efficiency of agricultural water pumps. The system uses an ESP32 microcontroller to continuously monitor important parameters such as voltage, current, temperature, moisture level, and pump security through dedicated sensors. By integrating IoT technology with intelligent protection mechanisms, the proposed system reduces maintenance costs, minimizes manual supervision, extends pump life, and ensures efficient irrigation management. The solution is cost-effective, user-friendly, and well suited for modern smart farming applications.*

Keywords: Smart Agriculture, ESP32, IoT, Water Pump Protection, Pump Monitoring, Voltage Sensor, Current Sensor, Temperature Sensor, Dry-Run Protection, Telegram Bot, Relay Module, Smart Irrigation.

I. INTRODUCTION

Agriculture is one of the most important sectors contributing to economic growth and food security worldwide. Irrigation plays a crucial role in improving agricultural productivity, and electric water pumps are extensively used to supply water to crops. However, agricultural pumps are often installed in remote areas where continuous monitoring is difficult. Faults such as over-voltage, over-current, overheating, dry-run operation, and equipment theft can lead to severe motor damage and increased maintenance costs [1]. Conventional pumping systems generally require manual supervision, making timely fault detection challenging [2].

Recent advancements in the Internet of Things (IoT) have enabled the development of intelligent agricultural monitoring systems that provide real-time data acquisition, remote monitoring, and automatic control [3]. The ESP32 microcontroller has emerged as a suitable platform for IoT-based applications due to its built-in Wi-Fi capability, high processing speed, and low power consumption [4]. By integrating multiple sensors with IoT communication, farmers can monitor the operating condition of water pumps from anywhere and receive instant notifications whenever abnormal conditions occur [5].

Several researchers have proposed smart irrigation and pump monitoring systems using wireless sensor networks, soil moisture sensors, cloud computing, and IoT technologies [6]. These systems have significantly improved irrigation efficiency and water conservation [7]. However, most existing solutions mainly focus on irrigation automation and do not provide complete protection against electrical faults, motor overheating, dry-run conditions, and pump theft [8]. The absence of integrated fault detection and remote alert mechanisms reduces system reliability and increases operational risks [9].

The proposed Smart Agri Pump Protection and Monitoring System addresses these limitations by integrating an ESP32 microcontroller, voltage sensor, current sensor, temperature sensor, moisture sensor, pressure switch, relay module, and Telegram Bot into a single IoT platform [10]. The system continuously monitors critical operating parameters and automatically disconnects the pump whenever unsafe conditions are detected [11]. Real-time monitoring through a Telegram Bot allows users to remotely start, stop, and monitor the pump while receiving instant fault notifications [12]. This intelligent approach improves pump safety, minimizes maintenance costs, enhances operational reliability [13],

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supports efficient water management [14], and contributes to the development of sustainable smart farming practices [15].

II. PROBLEM STATEMENT

Agricultural water pumps are essential for irrigation, but they are frequently affected by problems such as over-voltage, over-current, overheating, dry-run operation, and theft due to their installation in remote farming areas. Conventional pump systems require continuous manual monitoring and lack real-time fault detection, resulting in delayed response to abnormal conditions, motor damage, increased maintenance costs, water wastage, and reduced operational efficiency. Furthermore, the absence of remote monitoring and instant alert mechanisms makes it difficult for farmers to supervise pump performance effectively. Therefore, there is a need for a cost-effective IoT-based smart pump protection and monitoring system that can continuously monitor critical parameters, automatically protect the pump from faults, provide remote control, and send real-time notifications to ensure safe, reliable, and efficient agricultural irrigation.

III. OBJECTIVES

1. To develop an IoT-based smart system for real-time monitoring and protection of agricultural water pumps.
2. To detect and protect the pump from over-voltage, over-current, overheating, and dry-run conditions.
3. To provide remote monitoring and control of the pump using an ESP32 microcontroller and Telegram Bot.
4. To generate instant fault and theft alerts for timely response and improved pump security.
5. To enhance the safety, reliability, and operational efficiency of agricultural irrigation while reducing maintenance costs.

IV. LITERATURE SURVEY

1. Correa-Quiroz et al. (2025) – IoT System with ESP32 for Smart Drip Irrigation and Climate Monitoring in Greenhouses

Correa-Quiroz and co-authors proposed an IoT-based smart irrigation system using the ESP32 microcontroller for greenhouse applications. The system integrates DHT11, soil moisture, water level, and UV sensors to monitor environmental conditions. Sensor data is transmitted to the Arduino Cloud for real-time monitoring and remote control. Experimental results demonstrated approximately **35% reduction in water consumption** while improving irrigation efficiency and reducing operational costs. However, the system mainly focuses on irrigation management and does not provide electrical fault protection or anti-theft features for agricultural pumps.

2. Nazwa Amelia Purnama (2024) – IoT-Based Irrigation Control System with ESP32 for Sustainable Agriculture

This research presented an ESP32-based smart irrigation system that monitors soil moisture, water level, and flow rate for automated irrigation control. The collected data is transmitted to a smartphone-accessible IoT platform, allowing farmers to monitor irrigation remotely. The proposed system improves water management and minimizes manual intervention. Although effective for irrigation automation, it lacks protection against over-voltage, over-current, motor overheating, and pump security threats.

3. Boralkar and Kulkarni (2024) – IoT Based Smart Agriculture System Using ESP32

The authors developed a smart agriculture monitoring system using an ESP32 microcontroller and the ThingSpeak cloud platform. The system collects real-time data from soil moisture, temperature, humidity, CO_2, and motion sensors to assist farmers in monitoring crop conditions remotely. The proposed solution improves farm monitoring and decision-making through cloud-based analytics. However, it primarily focuses on environmental monitoring and does not include dedicated agricultural pump protection mechanisms or automatic fault isolation.

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4. Yunus Emre Kunt (2025) – Development of a Smart Autonomous Irrigation System Using IoT and AI

Kunt introduced an intelligent irrigation system that combines IoT technology with Artificial Intelligence for autonomous irrigation control. The system utilizes ESP32, soil moisture sensors, temperature and humidity sensors, rain sensors, relays, and an LSTM-based prediction model. Users can operate the system manually or through AI using the Blynk application. The proposed framework improves irrigation efficiency and water conservation; however, it does not address pump protection against electrical faults such as over-voltage, over-current, overheating, or theft.

5. Nidhi Jaiswal et al. (2025) – Smart Drip Irrigation Systems Using IoT

This review paper presents recent developments in IoT-enabled smart drip irrigation systems with emphasis on automation, wireless communication, cloud monitoring, and precision agriculture. The study discusses the integration of IoT, Artificial Intelligence, and advanced communication technologies for improving irrigation efficiency and crop productivity. It also highlights future trends in sustainable farming. However, the review indicates that most existing systems mainly focus on irrigation automation and provide limited attention to comprehensive pump protection, fault detection, and security monitoring, creating opportunities for more integrated smart agricultural pump protection systems.

V. WORKING OF SYSTEM

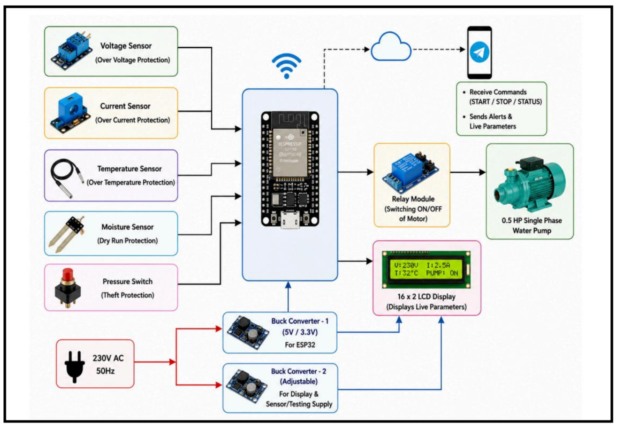

Fig 1: System architecture

A. Power Supply and Control Unit

The proposed Smart Agri Pump Protection and Monitoring System is powered by a 230 V AC supply, which serves as the primary power source for the entire system. Since the ESP32 microcontroller and peripheral modules require low-voltage DC power, two buck converters are used to convert the AC supply into regulated DC voltages. One converter provides a stable supply to the ESP32 microcontroller, while the other powers the sensors and the 16×2 LCD display. The ESP32 acts as the central processing unit of the system. It continuously receives data from all connected sensors, processes the information, compares the measured values with predefined threshold limits, and controls the operation of the relay module. In addition, the ESP32 provides Wi-Fi connectivity, enabling communication with the Telegram Bot for remote monitoring and control.

B. Sensing and Protection Unit

The sensing unit consists of multiple sensors that continuously monitor the operating condition of the agricultural water pump. The Voltage Sensor (ZMPT101B) measures the supply voltage and detects abnormal conditions such as over-voltage or under-voltage. The Current Sensor (ACS712) measures the current consumed by the motor and identifies overload or short-circuit conditions. A Temperature Sensor (DS18B20) continuously monitors the motor temperature to

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prevent overheating. The Moisture Sensor detects the availability of water and protects the pump from dry-run operation when sufficient water is unavailable. A Pressure Switch is installed to detect unauthorized movement or removal of the pump, providing anti-theft protection. All sensor readings are continuously transmitted to the ESP32 for analysis and decision-making.

C. Pump Protection and Monitoring Unit

Based on the sensor inputs, the ESP32 determines whether the pump is operating under safe conditions. If all parameters remain within their predefined limits, the Relay Module remains energized and supplies power to the 0.5 HP Single Phase Water Pump, allowing normal irrigation. If the ESP32 detects any abnormal condition such as over-voltage, excessive current, high temperature, dry-run operation, or theft, it immediately deactivates the relay to disconnect the pump from the power supply. This automatic protection mechanism prevents motor damage, reduces maintenance costs, and enhances the overall reliability and lifespan of the irrigation system.

D. Display and IoT Communication Unit

The monitoring unit provides both local and remote access to system information. A 16×2 LCD display continuously shows important parameters such as supply voltage, motor current, temperature, moisture status, and pump operating condition, allowing users to monitor the system directly at the installation site. Simultaneously, the ESP32 communicates with a Telegram Bot over Wi-Fi, enabling farmers to remotely monitor and control the pump using a smartphone. Users can send commands such as START, STOP, and STATUS, while the system automatically sends instant notifications whenever faults such as over-voltage, over-current, overheating, dry-run conditions, or theft are detected. This IoT-based communication improves user convenience, ensures timely fault response, and supports efficient and reliable agricultural irrigation.

V. SYSTEM DESIGN

The Smart Agri Pump Protection and Monitoring System is designed to provide continuous monitoring, fault protection, and remote control of agricultural water pumps using IoT technology. The system is built around the ESP32 microcontroller, which receives real-time data from multiple sensors, processes the information, and controls the pump through a relay module. It also communicates with a Telegram Bot for remote monitoring and instant fault notifications. The complete system consists of the following hardware and software components.

1. ESP32 Microcontroller

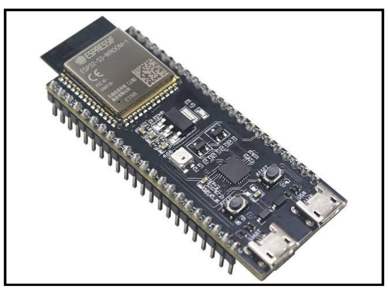

Fig 2: ESP32 central processing unit

The **ESP32** is the central processing unit of the proposed system. It is a 32-bit dual-core microcontroller with built-in Wi-Fi and Bluetooth capabilities, making it highly suitable for Internet of Things (IoT) applications. The ESP32 continuously reads data from all connected sensors, including voltage, current, temperature, moisture, and pressure sensors. It compares the measured values with predefined threshold limits and decides whether the pump should continue operating or be disconnected. The ESP32 also controls the relay module, updates the LCD display with live parameters, and communicates with the Telegram Bot to provide remote monitoring and control. Due to its high

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processing speed, low power consumption, and wireless communication capability, the ESP32 serves as the core of the entire system.

2. Voltage Sensor (ZMPT101B)

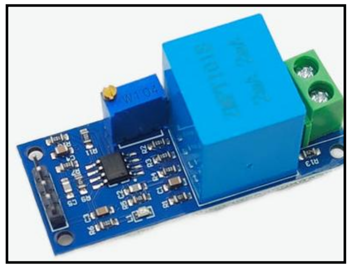

Fig 3: ZMPT101B Voltage Sensor

The ZMPT101B Voltage Sensor is used to monitor the AC supply voltage provided to the agricultural water pump. It continuously measures the input voltage and sends the measured values to the ESP32. If the supply voltage exceeds or falls below the safe operating range, the ESP32 immediately identifies the fault and disconnects the pump through the relay module. This protection prevents damage to the motor winding caused by voltage fluctuations, improves motor lifespan, and ensures safe pump operation.

3. Current Sensor (ACS712)

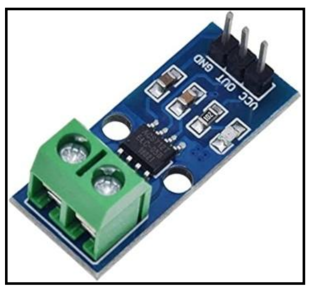

Fig 4: ACS712 Current Sensor

The ACS712 Current Sensor measures the current consumed by the water pump during operation. The sensor continuously monitors motor load conditions and detects abnormal situations such as overload, excessive current, or short circuits. Whenever the measured current exceeds the preset threshold, the ESP32 switches OFF the relay to protect the motor from overheating and electrical damage. Continuous current monitoring also helps identify motor health and improves system reliability.

4. Temperature Sensor (DS18B20)

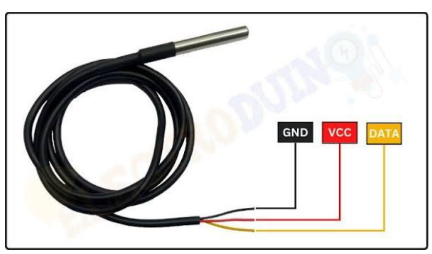

Fig 5: DS18B20 Digital Temperature

The DS18B20 Digital Temperature Sensor is used to monitor the operating temperature of the water pump motor. During continuous operation, excessive temperature may occur due to overload, mechanical failure, or insufficient

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cooling. The sensor sends real-time temperature data to the ESP32, which compares it with the maximum permissible limit. If overheating is detected, the controller disconnects the pump immediately and sends an alert notification to the user through the Telegram Bot. This feature significantly increases the operating life of the motor.

5. Moisture Sensor (Dry-Run Detection)

Fig 6: Moisture Sensor

The Moisture Sensor is used to detect the presence of water near the pump source. It prevents dry-run conditions, which occur when the pump continues to operate without sufficient water. Dry-run operation can severely damage the motor and reduce pump efficiency. The sensor continuously checks water availability, and if no water is detected, the ESP32 automatically switches OFF the relay to stop the pump. This protection conserves energy and prevents unnecessary motor wear.

6. Pressure Switch (Anti-Theft Sensor)

The **Pressure Switch** functions as an anti-theft mechanism in the proposed system. Agricultural pumps are often installed in isolated locations where theft is common. The pressure switch detects unauthorized movement or removal of the pump. When any abnormal movement is detected, the sensor immediately sends a signal to the ESP32. The controller activates the alarm mechanism and sends an instant theft notification to the farmer through the Telegram Bot. This feature enhances equipment security and minimizes financial losses.

7. Relay Module

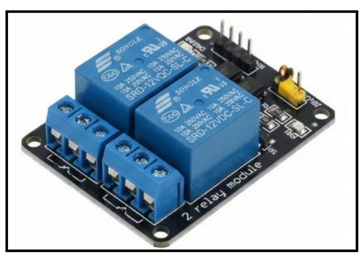

Fig 7: Relay Module

The Relay Module acts as an electrically controlled switch between the ESP32 and the water pump. Under normal operating conditions, the ESP32 energizes the relay, allowing power to flow to the pump. If any fault such as over-voltage, over-current, overheating, dry-run, or theft is detected, the ESP32 immediately deactivates the relay, disconnecting the pump from the electrical supply. The relay provides complete electrical isolation between the low-voltage control circuit and the high-voltage pump, ensuring safe system operation.

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8. 0.5 HP Single Phase Water Pump

Fig 8: 0.5 HP Single Phase Water Pump

The 0.5 HP Single Phase Water Pump is the primary load of the system and is responsible for supplying water to agricultural fields. The pump receives power through the relay module and operates only when all monitored parameters remain within safe operating limits. If any abnormal condition occurs, the pump is automatically stopped to prevent equipment damage and ensure reliable irrigation.

9. 16×2 LCD Display

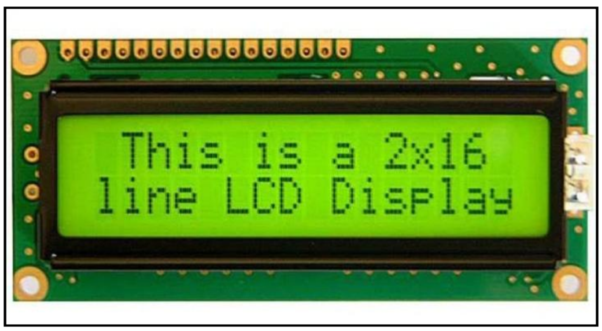

Fig 9: 16×2 LCD Display

The 16×2 LCD Display provides local visualization of the system status. It continuously displays important parameters such as supply voltage, motor current, temperature, moisture status, and pump operating condition. During fault conditions, the LCD also displays warning messages, allowing farmers to quickly identify the reason for pump shutdown without requiring additional monitoring equipment.

10. Telegram Bot

The Telegram Bot serves as the IoT-based remote monitoring and control platform. Using a smartphone with internet connectivity, users can remotely start or stop the pump and check its operating status by sending simple commands such as ON, OFF, and STATUS. The Telegram Bot also sends real-time notifications whenever faults such as over-voltage, over-current, overheating, dry-run, or theft are detected. This feature enables farmers to monitor irrigation systems from any location and respond immediately to abnormal conditions.

11. Buck Converters

Two **Buck Converters** are used to provide stable DC power to the electronic components. The first converter supplies the ESP32 microcontroller, while the second powers the LCD display and sensor modules. These converters reduce the input voltage to the required operating level with high efficiency, ensuring reliable performance of the entire monitoring system.

12. Arduino IDE

The **Arduino IDE** is used for developing and uploading the embedded C program to the ESP32 microcontroller. It provides an easy programming environment for configuring sensor interfaces, implementing protection algorithms, controlling the relay module, and integrating Wi-Fi communication with the Telegram Bot. The IDE also supports debugging and firmware updates, making system development and maintenance more efficient.

VI. RESULTS

The complete hardware setup of the Smart Agri Pump Protection System consists of an ESP32 microcontroller, various sensors, relay module, LCD display, power supply module, and a 0.5 HP single-phase water pump. The ESP32 acts as the central controller and continuously monitors voltage, current, temperature, and soil moisture parameters. A two-channel relay module is used to control the operation of the water pump. The measured parameters are displayed on the 16×2 LCD and transmitted to the owner's mobile phone through the Telegram bot. The system automatically disconnects the pump during over-voltage, over-current, over-temperature, dry-run, and theft conditions. Thus, the complete hardware setup provides reliable protection and remote monitoring for agricultural applications.

Model prototype

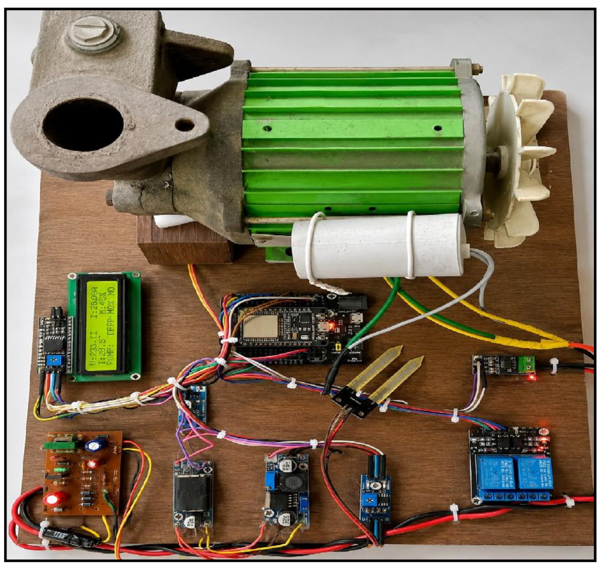

Fig 10: Model view 1

Fig 11: LCD Display Output

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Telegram Bot Status Message

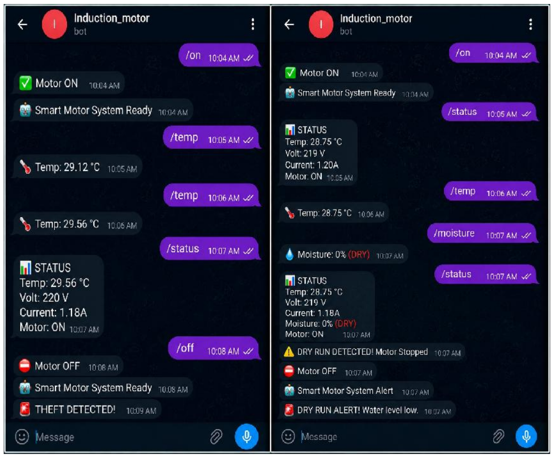

Fig 12: Telegram Bot Status Message

The Telegram Bot enables remote monitoring and control of the agricultural water pump. Users can operate the pump using commands such as **/on**, **/off**, and **/status**. It displays real-time information including voltage, current, temperature, moisture level, and pump status. The bot also sends instant notifications whenever faults such as dry-run or theft are detected, allowing farmers to monitor and control the system from anywhere.

Over-Voltage Fault Alert & Anti-Theft Alert Notification

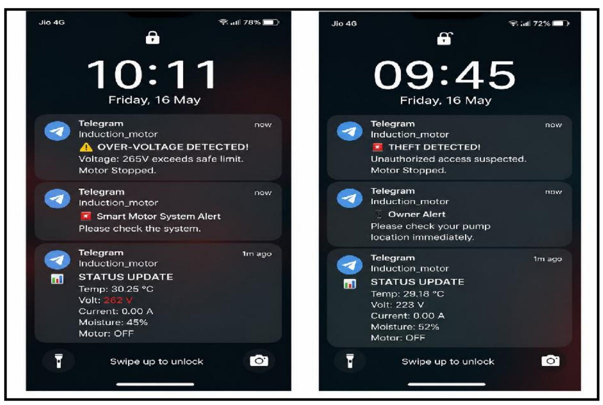

Fig 13: Over-Voltage Fault Alert & Anti-Theft Alert Notification

The Telegram Bot provides instant fault notifications whenever abnormal conditions such as over-voltage or theft detection occur. Upon detecting a fault, the ESP32 automatically switches OFF the pump to prevent damage and immediately sends an alert message to the user's mobile phone. This real-time notification system enhances the safety, security, and reliability of the Smart Agri Pump Protection and Monitoring System.

VII. CONCLUSION

The Smart Agri Pump Protection and Monitoring System provides a reliable and cost-effective IoT-based solution for protecting agricultural water pumps from faults such as over-voltage, over-current, overheating, dry-run conditions, and theft. The ESP32 continuously monitors system parameters, automatically disconnects the pump during abnormal conditions, and sends real-time alerts through the Telegram Bot. The system improves pump safety, reduces maintenance costs, minimizes manual supervision, and enhances the efficiency and reliability of agricultural irrigation.

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VIII. FUTURE SCOPE

The proposed system can be further enhanced by integrating cloud-based data storage for long-term performance analysis and predictive maintenance. AI and machine learning techniques can be incorporated to predict pump failures and optimize irrigation schedules. GPS-based location tracking and solar-powered operation can further improve system security and energy efficiency. Additionally, a dedicated mobile application and integration with smart farming platforms can provide more advanced monitoring and control features for modern precision agriculture.

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