# Smart Irrigation System Using Modbus RTU Protocol and Esp8266

**Vivek Jambhulkar[1], Aditya Dange[2]**

[1,2]Student, Instrumentation Engineering, (Vesit) Mumbai

**Abstract**

Irrigation is the practice of watering farmland to prepare it for agriculture, enabling the cultivation of crops and the maintenance of landscapes in areas with limited rainfall. This project focuses on the efficient use of groundwater, preventing wastage and overflow on farmland, through an IoT-based system utilizing moisture sensors connected to a microcontroller. The ESP8266 microcontroller is employed for its efficient performance and integrated Wi-Fi capabilities. The system leverages the Modbus RTU protocol to monitor wide areas of farmland, enabling reliable and scalable communication between devices. This system reduces the risk of low crop yields due to water shortages and supports automated irrigation, facilitating the analysis of different crop water consumption and soil characteristics.

**Keywords:** Modbus rtu protocol , Arduino Uno,Esp8266, max 485 module, Yl 69 Sensor , Pump , solenoid Valve,

## 1. Introduction

Efficient water management is a critical concern in modern agriculture, as it directly impacts crop yields and conserves valuable water resources. Traditional irrigation methods often lead to significant water wastage, reducing the overall efficiency of farming operations and increasing costs. To address these challenges, the integration of Internet of Things (IoT) technology into irrigation systems offers a promising solution by enabling precise monitoring and control of water usage, thus optimizing the irrigation process. This research focuses on the development of a **SMART IRRIGATION SYSTEM USING MODBUS RTU PROTOCOL AND ESP8266**, designed to enhance water usage efficiency in agricultural practices. The system automates the irrigation process by controlling water distribution based on real-time soil moisture data, ensuring that crops receive the optimal amount of water necessary for healthy growth.

At the core of the system are three YL-69 soil moisture sensors connected to an Arduino Uno microcontroller, which serves as the central processing unit. The Arduino Uno collects and processes moisture data from the sensors and is linked to a MAX485 module. This module enables communication using the Modbus RTU protocol, which is essential for transmitting data over longer distances and ensuring accurate monitoring of moisture levels across the entire farmland.

To provide real-time feedback, an I2C module is integrated with a 16x2 LCD screen, displaying current moisture levels and indicating the status of the irrigation pump. The ESP8266 microcontroller plays a crucial role by receiving signals from the Arduino Uno and controlling the pump accordingly. Based on the soil moisture data, the ESP8266 sends commands to the pump to turn it on or off, effectively managing water distribution and preventing wastage.

In addition to its core functionalities, the ESP8266 can be integrated with a mobile device, allowing users to remotely monitor and control the irrigation system. This mobile integration provides a user-friendly interface for viewing real-time data, adjusting settings, and receiving notifications about the system's status, further enhancing the convenience and effectiveness of the irrigation process.

This system not only automates the irrigation process but also offers scalable and efficient remote monitoring and control capabilities. By maintaining optimal soil moisture levels, the system minimizes the risk of water wastage, improves crop health, and ultimately contributes to higher crop yields. The integration of Modbus RTU protocol, ESP8266, and mobile device connectivity ensures reliable communication and control, making this system a robust solution for modern agricultural needs.

## 2. Prepare Your Paper Before Styling

**Proposed Methodology**

The development of the **SMART IRRIGATION SYSTEM USING MODBUS RTU PROTOCOL AND ESP8266** is structured into several critical phases, encompassing hardware integration, software development, and system validation. The following methodology outlines the systematic approach employed to design, implement, and evaluate the proposed irrigation system.

### I. System Design and Architecture

**Component Selection:**

- The first step involves selecting essential components, including YL-69 soil moisture sensors, an Arduino Uno microcontroller, a MAX485 module, an ESP8266 microcontroller, an I2C module, and a 16x2 LCD screen. These components were chosen based on their compatibility and effectiveness in achieving the system's objectives.
- Special attention is given to the communication protocols, particularly the Modbus RTU for reliable data transmission over long distances, and the ESP8266's ability to interface with mobile devices for remote monitoring and control.

**System Architecture Planning:**

The overall system architecture is designed, mapping out the interaction and communication pathways between components. This includes the connections from the moisture sensors to the Arduino Uno, the integration of the MAX485 module for Modbus RTU communication, and the linkage of the ESP8266 microcontroller for wireless connectivity and control functions.

### II. Hardware Integration

**Sensor Integration:**

Three YL-69 soil moisture sensors are interfaced with the Arduino Uno to continuously monitor soil moisture levels. These sensors provide analog signals that the Arduino Uno processes to determine the irrigation requirements.

**Communication Setup:**

- The MAX485 module is connected to the Arduino Uno, enabling communication through the Modbus RTU protocol. This setup ensures that the soil moisture data can be transmitted efficiently across the farmland, even over longer distances.
- The MAX485 module is further linked to the ESP8266 microcontroller, which is responsible for receiving the processed data and controlling the irrigation pump based on pre-set moisture thresholds.

**LCD Display Connection:**

An I2C module is connected to the 16x2 LCD screen and then interfaced with the ESP8266 microcontroller. The LCD screen provides a real-time display of soil moisture levels and indicates the operational status of the irrigation pump, offering immediate visual feedback.

**ESP8266 Configuration:**

The ESP8266 microcontroller is programmed to receive moisture data from the Arduino Uno and to control the irrigation pump accordingly. Wi-Fi connectivity is established on the ESP8266, enabling the system to communicate with a mobile device for remote operation.

## III. Software Development

**Arduino Programming:**

Custom code is developed for the Arduino Uno to read and process the sensor data, manage the Modbus RTU communication with the MAX485 module, and execute logic for the irrigation control based on the soil moisture readings.

**ESP8266 Firmware Development:**

The firmware for the ESP8266 is created to handle data communication via Modbus RTU, receive soil moisture readings, and control the irrigation pump. Wi-Fi protocols are implemented to enable the ESP8266 to connect with a mobile device for remote system management.

**Mobile Interface Design:**

A user-friendly mobile application or web interface is designed to connect with the ESP8266. This interface allows users to monitor real-time soil moisture data, manually control the irrigation pump, and receive system alerts.

## IV. System Testing and Calibration

**Sensor Calibration:**

The YL-69 soil moisture sensors are calibrated to ensure accurate readings under various environmental and soil conditions. Calibration is crucial for the reliable operation of the system.

**Communication Testing:**

The communication between the Arduino Uno, MAX485 module, and ESP8266 is rigorously tested to confirm the stability and accuracy of data transmission using the Modbus RTU protocol.

**Pump Control Verification:**

The functionality of the ESP8266 in controlling the irrigation pump is verified, ensuring that the pump responds correctly to moisture data and commands received from the mobile interface.

**Integration Testing:**

A comprehensive end-to-end test of the entire system is conducted, ensuring that all components, including the mobile integration, function together seamlessly.

**System Optimization:**

Based on the testing results, the system is optimized for power efficiency and operational reliability, ensuring that it meets the practical requirements of agricultural environments.

## V. Deployment and Field Testing

**Field Deployment:**

The system is deployed in an actual agricultural setting to evaluate its performance under real-world conditions. This phase involves installing the system in a designated farmland area and monitoring its operation over time.

**Data Collection:**

sSoil moisture levels, water usage, and crop growth data are collected continuously to assess the system's impact on irrigation efficiency and crop health.

**User Feedback:**

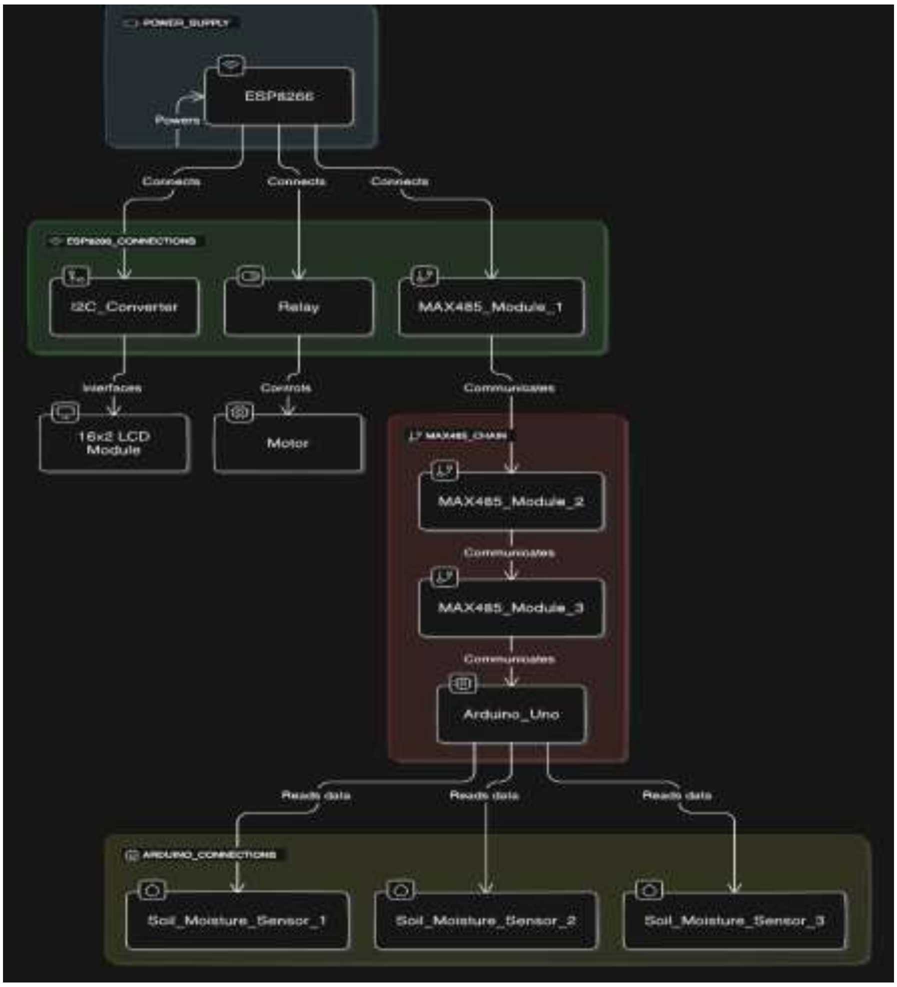
Feedback from users interacting with the system via the mobile interface is gathered to assess usability, functionality, and overall satisfaction with the system's performance.

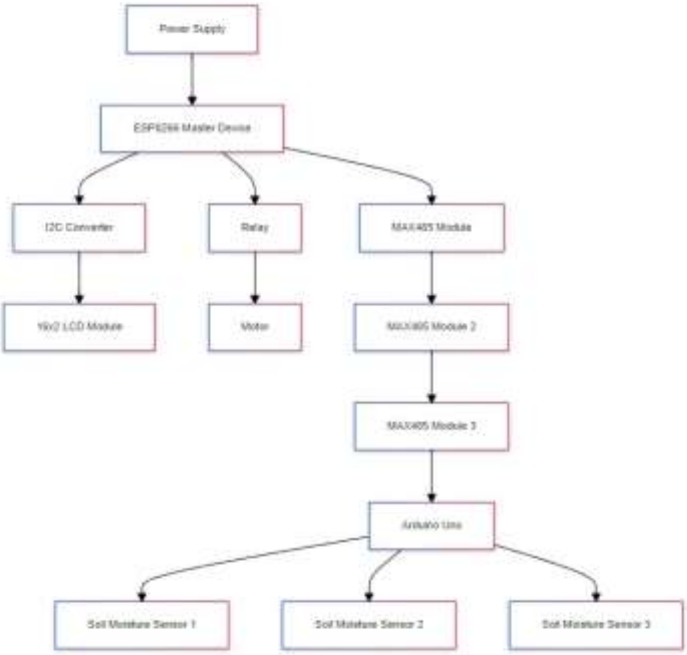
## VI. Analysis and Reporting

**Performance Evaluation:**

- The collected data is analyzed to evaluate the system's effectiveness in optimizing water usage, maintaining optimal soil moisture levels, and improving crop yields. The analysis also considers the system's scalability and adaptability to different agricultural scenarios.
- Documentation and Reporting:
- The research findings are thoroughly documented, with a focus on the system's strengths, potential improvements, and future research directions. The results are compiled into a final report, presenting the outcomes and implications of the study.

## 3. Diagrams and Flowcharts






## 4. System Implementations

### I. Power Supply:

The power supply is a crucial component of the smart irrigation system, providing the necessary voltage and current to the ESP8266 and other connected devices. A stable 5V DC power supply is selected to match the voltage requirements of the ESP8266, relay, and other peripherals. This power source is designed to handle a minimum of 1A current to ensure reliable operation across the system. Additionally, voltage regulators are used if specific components require different voltage levels. Over-voltage and over-current protection features are incorporated to safeguard the system from electrical anomalies, ensuring continuous and safe operation.

### II. ESP8266:

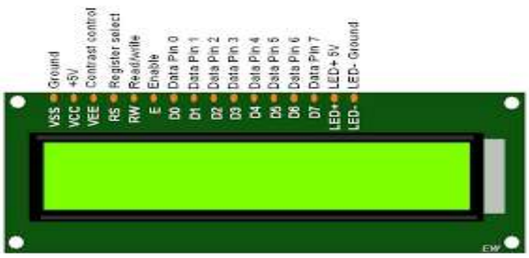
The ESP8266 serves as the master controller of the irrigation system, coordinating communication and control tasks. Equipped with a Tensilica L106 32-bit RISC processor running at 80-160 MHz, the ESP8266 is powerful enough to manage various system functions. It provides integrated Wi-Fi connectivity (802.11 b/g/n), allowing for remote monitoring and control via a mobile device. The ESP8266 interfaces with multiple components, including an I2C module for the LCD display, a relay for motor control, and a MAX485 module for Modbus RTU communication. With its flash memory of 4MB and multiple GPIO pins, the ESP8266 can be programmed to handle various tasks such as data processing, device control, and communication with peripheral devices.

### III. I2C Converter:

The I2C converter plays a vital role in facilitating communication between the ESP8266 and the 16x2 LCD module. Operating on the I2C protocol, this converter simplifies wiring by requiring only four connections: VCC, GND, SDA, and SCL. It enables the ESP8266 to send real-time data to the LCD for display. The I2C bus is equipped with pull-up resistors to ensure stable communication, supporting data rates up to 400 kHz. This setup allows for efficient and reliable data transfer, making it easier to monitor the system's status and soil moisture levels.


### IV. 16x2 LCD Module:

The 16x2 LCD module is responsible for displaying real-time data such as soil moisture levels and motor status. Connected via an I2C interface, the LCD module requires minimal wiring, which enhances the system's simplicity and reliability. It operates at 5V and features adjustable backlighting for improved visibility. The display format and content are customized through the ESP8266 using the `LiquidCrystal_I2C` library, ensuring that critical information is clearly presented to the user. This module plays a crucial role in providing real-time feedback to operators, making the system user-friendly and easy to monitor.




### V. Relay:

The relay is a key component in the irrigation system, controlling the operation of the water pump (motor). Connected to one of the ESP8266's GPIO pins, the relay is programmed to activate or deactivate the motor based on the moisture data received from the soil sensors. This relay module operates on a 5V signal and can handle loads up to 10A at 250V AC or 30V DC. It features optocoupler-based isolation, ensuring that the control circuit remains protected from high-voltage spikes. This robust and reliable switching mechanism is essential for the automated control of irrigation, ensuring water is pumped only when needed.

### VI. Motor (Water Pump):

The motor, controlled by the relay, is responsible for pumping water to the field as required. The motor is selected based on the irrigation area and is typically rated between 50W to 1kW, depending on the system's scale. It operates at 12V, 24V, or 230V AC, depending on the power supply and system design. The motor's flow rate is carefully chosen to match the irrigation needs, and it is equipped with overload protection or thermal cut-off features to prevent damage during operation. The motor is a critical component in ensuring the efficient delivery of water to the crops, directly impacting the system's effectiveness in maintaining soil moisture levels.

**VII. MAX485 Modules:**

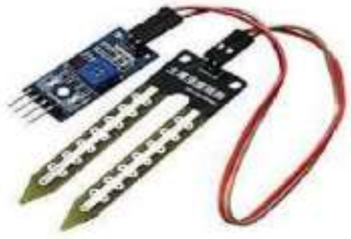
The MAX485 modules facilitate communication between the ESP8266 and Arduino Uno using the RS-485 protocol. These modules enable robust data transmission over long distances, making them ideal for large-scale irrigation systems. The MAX485 modules operate on a 5V supply and support communication distances up to 1200 meters with data rates up to 2.5 Mbps. The half-duplex operation of these modules allows for efficient use of a single twisted pair cable for data transmission, while the Modbus RTU protocol ensures reliable communication between the ESP8266 and the Arduino Uno. Proper termination and configuration of the modules are essential for preventing signal reflections and ensuring data integrity.

**VIII. Arduino Uno:**

The Arduino Uno, powered by the ATmega328P microcontroller, serves as the interface for the soil moisture sensors. It reads analog signals from the sensors, converts them to moisture levels, and transmits the data to the ESP8266 via the MAX485 modules. Operating at 5V, the Arduino Uno is equipped with 6 analog input pins and features communication protocols such as UART, SPI, and I2C. With 32 KB of flash memory, 2 KB of SRAM, and 1 KB of EEPROM, the Arduino Uno is programmed to handle sensor data processing and Modbus RTU communication. It plays a vital role in accurately monitoring soil conditions and ensuring the efficient operation of the irrigation system.

**IX. Soil Moisture Sensors:**

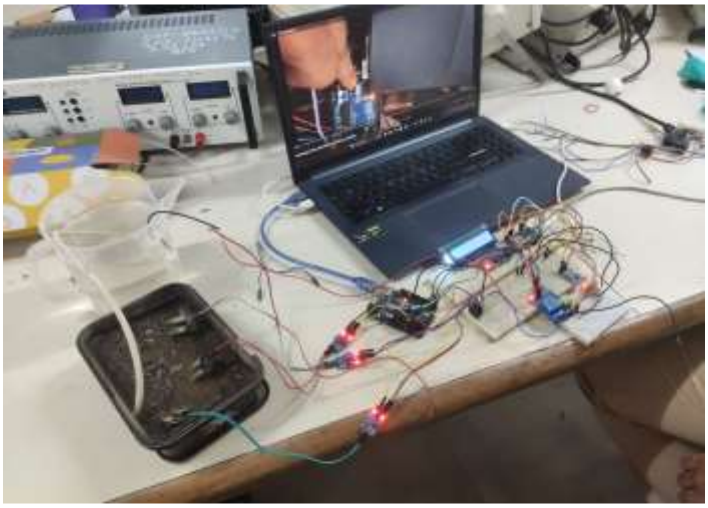
The soil moisture sensors are critical for measuring the moisture content in the soil, providing essential data for irrigation control. Typically, resistive or capacitive sensors are used, operating at 3.3V or 5V. These sensors output an analog voltage proportional to the soil moisture level, which is read by the Arduino Uno. The sensors are calibrated to provide accurate readings across a range of soil conditions, with a measurement range of 0% to 100% soil moisture. Fast response times ensure that the system can make real-time adjustments to irrigation, preventing both under-watering and over-watering, which are crucial for optimizing crop yields and water usage.

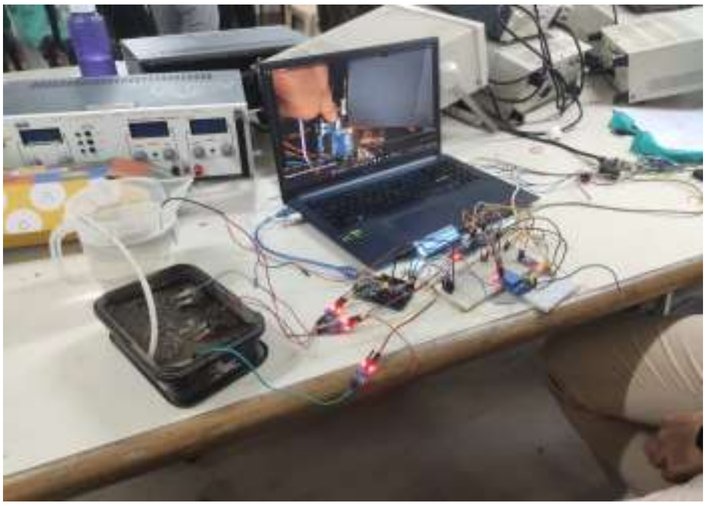


## 5. RESULTS AND DISCUSSIONS:

The smart irrigation system designed using the ESP8266 as the master controller demonstrated significant improvements in water management efficiency. The system effectively maintained optimal soil moisture levels by accurately reading data from three soil moisture sensors connected to the Arduino Uno. The relay-controlled motor, activated based on real-time moisture data, ensured that water was supplied only when necessary, preventing both under-irrigation and over-irrigation. The integration of the I2C module with the 16x2 LCD provided real-time monitoring and control feedback, enhancing the system's usability. The Modbus RTU protocol facilitated robust and reliable communication between the ESP8266 and Arduino Uno over extended distances, making it suitable for large-scale agricultural applications. The inclusion of MAX485 modules in the system allowed for efficient data transmission over long distances, ensuring that even remote sections of the farmland were adequately monitored and irrigated. Additionally, the system's ability to integrate with a mobile device provided a convenient platform for remote monitoring and control, allowing users to manage irrigation operations from anywhere. This feature significantly increases the system's practicality and usability in real-world scenarios, where timely interventions can be crucial.

The system's design also allowed for scalability, making it adaptable to various farm sizes and types. The use of commonly available components such as the ESP8266, Arduino Uno, and soil moisture sensors ensures that the system is both cost-effective and easy to maintain. Overall, the results indicate that this smart irrigation system can significantly contribute to water conservation and improved crop yields by automating the irrigation process based on real-time soil moisture data. The discussion of these results highlights the potential for further development and refinement, including the integration of additional sensors or advanced data analytics for even more precise irrigation management.





## 6. CONCLUSION:

The implementation of a smart irrigation system using the ESP8266 and Modbus RTU protocol has proven to be an effective solution for optimizing water usage in agriculture. This system automates irrigation based on real-time soil moisture data, ensuring that crops receive the appropriate amount of water while conserving resources. Its modular design, incorporating components such as the Arduino Uno, MAX485 modules, and soil moisture sensors, provides flexibility and scalability, making it suitable for various agricultural applications. The integration with mobile devices for remote monitoring and control further enhances its practicality, allowing for timely adjustments that improve crop management and productivity. Overall, this research demonstrates that integrating IoT technologies into agriculture can significantly enhance efficiency and sustainability, offering a cost-effective, scalable, and user-friendly solution for better resource management and higher crop yields.

## 7. REFERENCES

1. Shivang Raj, Saksham Sehrawet, Nikhil Patwari Sathiya Kumar C . "IoT based model of automated agricultural system in India". Proceedings of the Third International Conference on Trends in Electronics and Informatics (ICOEI 2019) IEEE Xplore Part Number: CFP19J32-ART; ISBN: 978-1-5386-9439-8.
2. Kayode E. Adetunji, Meera K. Joseph. "Development of a Cloud-based Monitoring System using 4duino: Applications in Agriculture". 2018 International Conference on Advances in Big Data, Computing and Data Communication Systems (icABCD).
3. Monica M , B.Yeshika , Abhishek G.S , Sanjay H.A ,Sankar Dasiga. "IoT Based Control and Automation of Smart Irrigation System". Proceeding International conference on Recent Innovations is Signal Processing and Embedded Systems (RISE -2017) 27-29 October,2017
4. Vaishali S, Suraj S, Vignesh G, Dhivya S and Udhayakumar S. "Mobile Integrated Smart Irrigation Management and Monitoring System Using IOT". International Conference on Communication and Signal Processing, April 6-8, 2017, India
5. NodeMCU ESP8266 Pinout, Specifications, Features & Datasheet (components101.com)
6. MAX485 Datasheet and Product Info | Analog Devices
7. UNO R3 | Arduino Documentation
8. electronicoscaldas.com/datasheet/YL-69-HL-69.pdf

9. https://www.vishay.com/docs/37484/lcd016n002bcfhet.pdf
10. https://www.makershop.de/download/I2C-LCD-interface.pdf