Design of a Prototype of Smart Agriculture Powered by SPV

by

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Report on

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Table of Contents

List of Figures

List of Tables

ABSTRACT

This project presents an IOT based smart irrigation system in order to optimize watering schedules for plants and lawns. The system uses an Arduino Uno microcontroller in conjunction with IoT(Internet of Things) sensors to measure soil moisture, temperature, and humidity, as well as a weather station to collect data on ambient conditions. The microcontroller processes this information and controls irrigation valves or motors to deliver water only when necessary. The system also includes a user interface for manual control and scheduling, and it can be connected to a network for remote monitoring and management. To further improve the sustainability and efficiency of the system, the project integrates a water fetching system that draws water from a well.

This allows the system to supplement the water supply for irrigation and reduces reliance on external sources of water. In addition, the project incorporates a solar tracking system that maximizes energy generation from the solar panels to recharge the battery that powers the microcontroller. The results of the study demonstrate that the smart irrigation system significantly reduces water usage and enhances plant health when compared to traditional irrigation methods. This project presents a promising solution to the challenges of water scarcity and inefficient irrigation practices and has the potential to contribute to the development of more sustainable and environmen- tally friendly systems.

Chapter 1

1.1. Introduction

Technological advances in agriculture may provide answers to controlling the yield of a crop in response to varying climate con- ditions *[1,2]*. Reference *[3]* has presented the use of instruments to measure soil properties automatically. Following the trend of using technological advances to improve the quality and yield of crops, this work focuses on a smart irrigation system, which can fulfill its energy requirements from renewable energy sources like solar energy.

Farmers usually control the water flow to crops depending on the needs of a crop. Such needs depend on the surrounding temperature, soil moisture, time of the day, and health of a crop. Excess or insufficient irrigation can lead to a low yield of crops. Water scarcity is serious *[4]* and makes irrigation difficult. In remote locations, far-away from major water sources, irrigation mostly relies on.

The system uses an Arduino Uno microcontroller in conjunction with IoT(Internet of Things) sensors to measure soil moisture, temperature, and humidity, as well as a weather station to collect data on ambient conditions. The microcontroller processes this information and controls irrigation valves or motors to deliver water only when necessary. The system also includes a user interface for manual control and scheduling, and it can be connected to a network for remote monitoring and management. To further improve the sustainability and efficiency of the system, the project integrates a water fetching system that draws water from a well. This allows the system to supplement the water supply for irrigation and reduces reliance on external sources of water. In addition, the project incorporates a solar power system that maximizes energy generation from the solar panels to recharge the battery that powers the microcontroller. The results of the study demonstrate that the smart irrigation system significantly reduces water usage and enhances plant health when compared to traditional irrigation methods. This project presents a promising solution to the challenges of water scarcity and inefficient irrigation practices and has the potential to contribute to the development of more sustainable and environmentally friendly systems.

1.2. Objectives

The objective of this project is to optimize the use of water resources for irrigation by using sensor technology and weather data to automatically adjust irrigation schedules based on real- time conditions. This can help to conserve water, improve crop yields, and reduce costs. Additionally, the system can be designed to monitor soil moisture, weather forecast, and other factors to provide optimal watering schedule for the plants.

1. To Develop an IoT-enabled smart irrigation system that integrates water storage and solar tracking to optimize resource allocation and conserve water.
2. To Integrate a range of IoT sensors and weather station into the smart irrigation system for real-time monitoring and analysis of environmental conditions.
3. To Implement a user-friendly mobile application for remote monitoring and control of the smart irrigation system.
4. To Evaluate the effectiveness of the IoT-based smart irrigation system in reducing water usage and improving plant health compared to traditional irrigation methods. By combining these objectives, our project aims to develop an innovative and comprehensive IoT-enabled smart irrigation system that integrates water storage and solar tracking, while providing real-time monitoring and control through a user-friendly mobile application.

1.3. Expected Outcomes

The expected outcomes of this project include increased water efficiency through real- time adjustment of irrigation schedules based on weather data, leading to reduced water waste. The system also contributes to improved crop yields by optimizing irrigation schedules for healthier plants and increased productivity. Energy efficiency is enhanced by adjusting irrigation based on weather conditions, reducing the need for pump operations and lowering energy consumption. Better management of irrigation schedules and water usage enables farmers and landscapers to make informed decisions, while monitoring capabilities prevent overwatering and under watering. This leads to better crop quality by providing the right amount of water at the right time, minimizing plant stress and improving overall crop health. The developed system also promotes environmental sustainability by conserving water and reducing waste, protecting water resources and minimizing negative environmental impacts. The integration of a user-friendly mobile application enables remote monitoring and control, allowing real-time adjustments to irrigation schedules, monitoring of soil moisture levels, and receiving alerts or notifications about system performance. Additionally, the system generates valuable data on soil moisture, weather conditions, and water usage, facilitating data-driven decision making for optimizing irrigation strategies, improving water management, and enhancing crop health.

1.4 Motivation and background

Our motivation to work on this project is to address the challenges faced by farmers in our region with traditional farming methods. By using renewable technology and IoT, we aim to make farming more efficient, reduce energy consumption, and minimize environmental impact. As electrical engineering students, this project will help us develop skills in sensor technology and IoT while gaining expertise in solar panel technology. Our goal is to improve the living conditions of local farmers and promote sustainable agriculture. Our motivation is to make a positive impact, acquire technical skills, and contribute to farming society and sustainable development

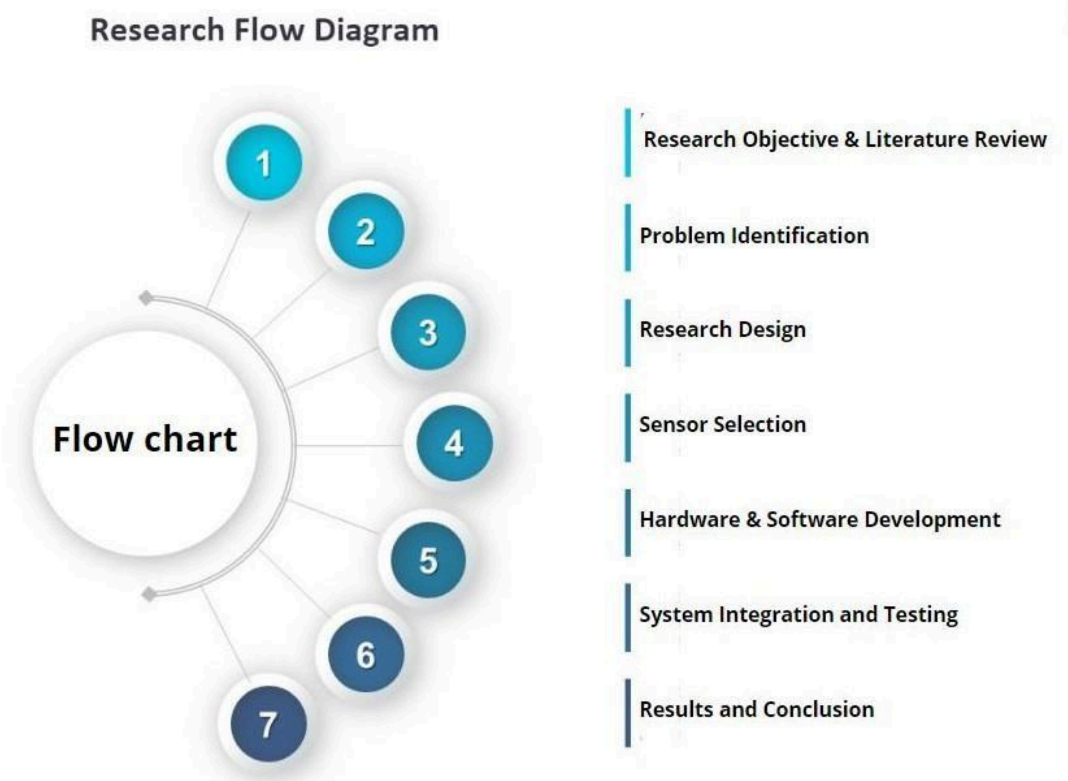

Figure 1.1 : Research Flow Diagram

Overall, the research flow diagram for this project provides a visual representation of the key stages, processes, and outcomes of the research project. It serves as a guide to ensure a systematic and well-structured approach to the development and evaluation of the smart irrigation system.

1.5 Thesis Organization

This report contains five different chapters that are structured as follows.

1. In Chapter one, an introduction on the research keywords have been discussed and the following key points were developed.
    - Internet of things (IOT) and sensors (soil moisture sensor, temperature and humidity sensor, proximity sensor)
    - Research objectives
    - Expected outcomes

2. In the second chapter some literatures have been reviewed on studies done in modern irrigation practices and contains the following sections.
    - Overview of traditional irrigation methods and their limitations
    - Introduction to IoT and its applications in agriculture
    - Review of existing research and developments in IoT-based smart irrigation systems
    - Analysis of the advantages and challenges associated with smart irrigation technologies

3. In the third chapter, a methodology on various devices used as well as the implementation procedures has been elaborated as follows.
    - Description of the hardware and software components used in the smart irrigation system
    - Details of the IoT sensors and weather station integrated into the system
    - Overview of the data collection and analysis techniques employed
    - Design and Development of IoT-Enabled Smart Irrigation System
    - System architecture and components
    - Integration of water storage and solar tracking mechanisms
    - Implementation of real-time monitoring and analysis using IoT sensors and weather station

- Development of the user-friendly mobile application for remote monitoring and control

4. In the fourth chapter the results obtained from multiple experiments done have been showed on various soil and environment conditions.
   - Experiment 1: Water Fetching
   - Experiment 2: Dry soil
   - Experiment 3: Wet soil
   - Experiment 4: Solar Power system

5. The final chapter contains the discussions on the result obtained and the conclusion on the entire work done followed by some suggestions on further works.

6. The reference part contains all the sources on the literature reviewed earlier

7. The Appendix section contains the Arduino code of the project.

Chapter 2

2.1. Literature review

Smart agriculture, which leverages Internet of Things (IoT) technologies and renewable energy sources such as solar power, is transforming traditional farming practices. This approach aims to enhance productivity, reduce resource wastage, and ensure sustainability. This literature review explores various research studies and implementations of IoT and solar energy in smart agriculture, highlighting the benefits, challenges, and future directions.

1. IoT in Smart Agriculture

IoT technologies enable the integration of various sensors and devices to collect real-time data from agricultural fields. This data can be used to monitor environmental conditions, automate irrigation systems, and optimize resource usage.

[5] IoT-based smart agriculture systems can significantly improve crop yield and quality by providing precise control over farming processes. Sensors can monitor soil moisture, temperature, humidity, and light levels, allowing farmers to make informed decisions and respond quickly to changing conditions .

2. Solar Energy in Smart Agriculture

Solar energy is a sustainable and cost-effective solution for powering IoT devices and systems in agriculture. The integration of solar panels can ensure continuous power supply, especially in remote areas with limited access to electricity.

[6] demonstrates that solar-powered irrigation systems can reduce operational costs and

dependence on non-renewable energy sources. By using photovoltaic panels to power water pumps and sensors, these systems provide a reliable energy source that supports continuous operation and reduces environmental impact .

3. IoT and Solar-Powered Smart Irrigation Systems

Combining IoT with solar energy in smart irrigation systems has shown promising results in improving water use efficiency and crop productivity. These systems use data from soil moisture sensors to optimize irrigation schedules, reducing water wastage.

[7]IoT-based smart irrigation systems powered by solar energy can save up to 30% of water compared to traditional irrigation methods. The integration of real-time monitoring and control allows for precise water application based on the actual needs of the crops .

4. Case Studies and Implementations

Several case studies illustrate the practical benefits of IoT and solar-powered smart agriculture systems. For instance, a pilot project in India implemented by Jain Irrigation Systems showed a 20% increase in crop yield and a 40% reduction in water usage by using a solar-powered IoT irrigation system [8] .

Another example is a project in Spain where IoT sensors and solar energy were used to monitor and control greenhouse conditions. [9] significant improvements in crop growth rates and energy efficiency, demonstrating the viability of this approach for large-scale agricultural operations .

5. Challenges and Future Directions

Despite the advantages, there are challenges in implementing IoT and solar-powered systems in agriculture. These include high initial costs, technical complexities, and the need for reliable internet connectivity. Additionally, the integration of these technologies requires proper training and awareness among farmers.

Future research should focus on developing cost-effective solutions, improving the scalability of IoT systems, and enhancing the efficiency of solar energy conversion. Collaborative efforts between governments, research institutions, and private sectors can facilitate the adoption of these technologies and ensure their long-term sustainability.

Conclusion

The integration of IoT and solar energy in smart agriculture presents a promising solution for enhancing agricultural productivity and sustainability. While there are challenges to overcome, the benefits of improved resource efficiency, reduced environmental impact, and increased crop yields make this an area of significant interest for future research and development.

Chapter 3

3. Methodology

3.1. Proposed System

The proposed smart irrigation system is designed to optimize water usage and enhance irrigation practices through the integration of various components and features. Let's take a closer look at each component and its role in the system:

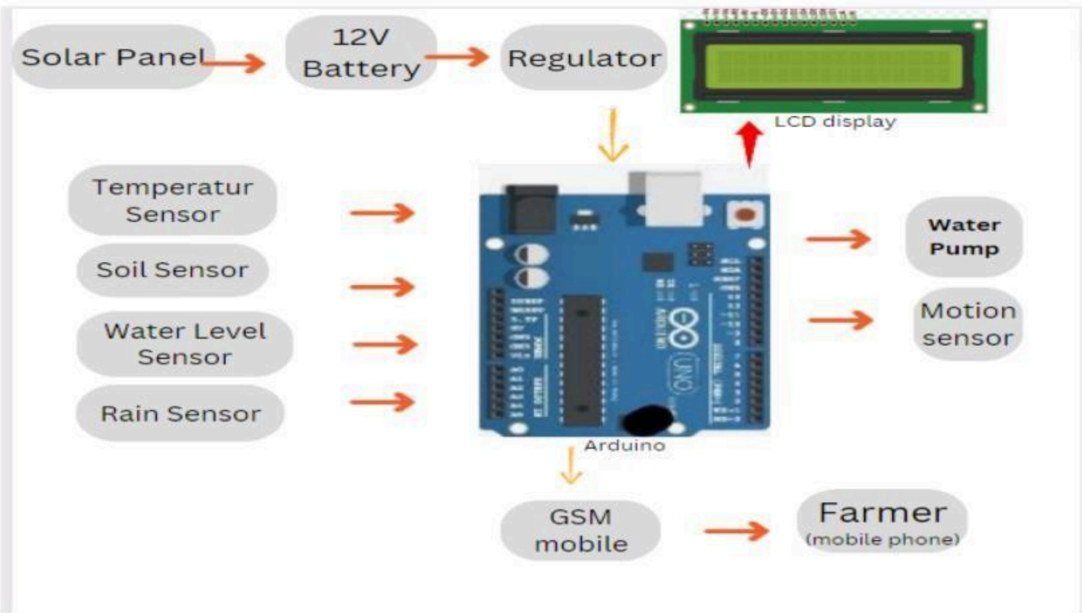

Fig 3.1: Proposed system diagram

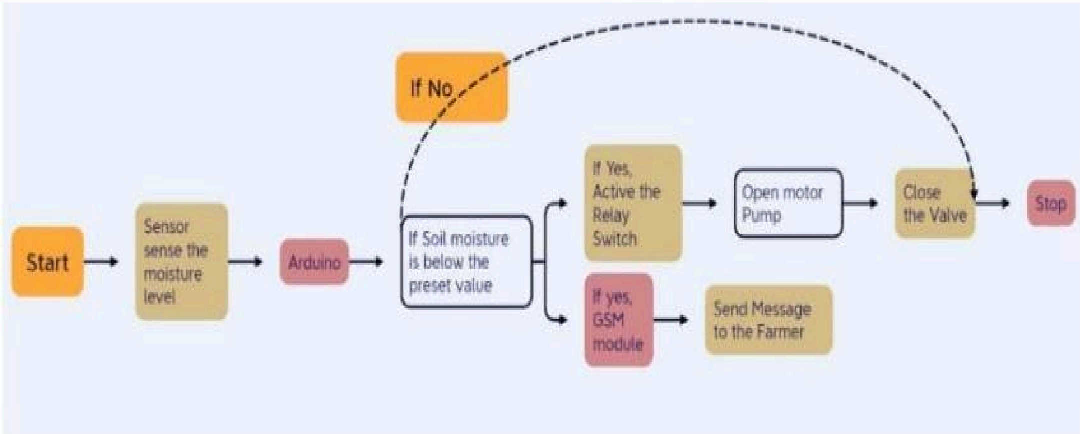

Fig 3.2: Algorithm of the Proposed system diagram

- IoT Sensors: The system incorporates IoT sensors to measure crucial parameters such as soil moisture, temperature, and humidity. These sensors provide real-time data on the moisture levels and environmental conditions in the soil, enabling the system to make informed decisions regarding irrigation. By continuously monitoring the soil moisture content, the system can determine the precise watering needs of the plants, preventing under or over-watering.
- Weather Station: A weather station is integrated into the system to gather data on ambient conditions such as temperature, humidity, wind speed, and rainfall. This data helps in understanding the external factors that can influence the irrigation requirements of the plants. By considering the weather conditions, the system can adjust the irrigation schedules accordingly. For example, if there is recent rainfall, the system may delay or skip the irrigation cycle to avoid over-watering.
- Water Fetching System: The system includes a water fetching system that can draw water from a well or other water sources. This system acts as a supplementary water supply for irrigation, reducing reliance on external sources and promoting self-sustainability. The system can automatically fetch water from the designated source and distribute it to the plants as needed, ensuring efficient water usage.
- Solar Power System: To ensure a continuous power supply, the smart irrigation system incorporates solar panels. These panels maximize energy generation by harnessing sunlight throughout the day. The solar energy collected is used to recharge the system's battery, ensuring uninterrupted operation even in areas with limited access to electricity.
- Arduino Microcontroller: Serving as the central processing unit of the system, the

Arduino microcontroller collects and processes the data obtained from the IoT sensors and weather station. It uses intelligent control algorithms to analyze the data and make informed decisions about irrigation schedules. The microcontroller controls the irrigation valves or motors, ensuring that water is delivered only when required based on the analyzed data. This precise control helps to minimize water waste and improve irrigation efficiency.

- User Interface and Remote Access: The smart irrigation system incorporates a user-friendly interface that allows farmers to control and monitor the system using their mobile phones via SMS. This method provides a simple and accessible way for users to manage the irrigation system on the go. Farmers can adjust irrigation schedules, monitor sensor data, and receive real-time notifications and alerts about the system's status directly through SMS.

  Additionally, the SMS-based control functionality enables remote access, allowing farmers to securely connect to the system from anywhere without needing an internet connection. This means that farmers can monitor and control the irrigation system even when they are not physically present at the site. They can remotely adjust irrigation schedules, check real-time sensor data, and receive critical notifications. This remote access feature adds flexibility and convenience, empowering farmers to make informed decisions about irrigation practices from anywhere at any time.

3.1.1 IOT Sensors

The IoT sensors integrated into the smart irrigation system play a crucial role in monitoring and gathering real-time data on important parameters such as soil moisture, temperature, and humidity. Let's take a closer look at each of these sensors and their functions:

- Soil Moisture Sensor: The soil moisture sensor is designed to measure the moisture content present in the soil. It provides valuable information about the hydration levels of the soil, indicating whether the soil is dry or adequately moist. By continuously monitoring the soil moisture content, the sensor enables the system to determine when and how much water should be delivered to the plants. This helps in preventing under- watering or over-watering, as the system can adjust the irrigation schedule based on the specific moisture requirements of the plants.

- Temperature Sensor: The temperature sensor is responsible for measuring the ambient temperature in the vicinity of the plants or in the soil. Temperature plays a crucial role in plant growth and water requirements. Extreme temperatures can affect the plants' ability to absorb water and nutrients effectively. By monitoring the temperature, the sensor provides valuable data for the system to consider when determining irrigation schedules. For instance, during hot weather, the system may increase the frequency or duration of irrigation to compensate for increased evaporation rates.
- Humidity Sensor: The humidity sensor measures the level of moisture present in the air or the surrounding environment. High humidity levels can affect the plants' ability to transpire and may require adjustments to the irrigation schedule. The humidity sensor provides real-time data on the humidity levels, allowing the system to factor in this information when making irrigation decisions. It ensures that the irrigation schedule aligns with the specific humidity conditions, promoting optimal plant growth and health.
- By incorporating these IoT sensors into the smart irrigation system, the system can gather accurate and up-to-date data on soil moisture, temperature, and humidity. This data enables the system to make informed decisions regarding irrigation schedules and water delivery to the plants. By preventing under-watering or over-watering, the system ensures that the plants receive the precise amount of water they require for healthy growth. This not only conserves water resources but also promotes optimal plant health and reduces the risk of plant stress or diseases caused by improper irrigation practices.

3.1.2. Weather Station

The weather station is an essential component of the smart irrigation system as it provides valuable information about the external environmental conditions that can influence the irrigation requirements of the plants. It consists of various sensors and instruments that measure parameters such as temperature, humidity, wind speed, and rainfall. Let's delve deeper into the role and significance of the weather station in the system:

- Temperature: The temperature sensor in the weather station measures the ambient temperature in the surrounding area. Temperature affects plant growth and water requirements. High temperatures can increase evaporation rates and lead to higher water demand, while low temperatures can slow down plant growth. By monitoring temperature data, the system can adjust the irrigation schedule accordingly. For instance, during hot weather, the system may increase the frequency or duration of irrigation to compensate for increased evaporation.
- Humidity: The humidity sensor in the weather station measures the moisture content present in the air. Humidity levels impact plant transpiration rates and influence the need for irrigation. High humidity can reduce the rate of water loss from plants, whereas low humidity can increase the rate of evaporation. By considering humidity data, the system can fine-tune the irrigation schedule to align with the prevailing atmospheric moisture conditions.
- Rainfall: The rainfall sensor in the weather station detects the amount of rainfall in the area. Rainfall provides natural irrigation to the plants and incorporating this information into the system allows for more precise irrigation control. If the weather station registers recent rainfall, the system can adjust the irrigation schedule accordingly. It may delay or skip the irrigation cycle to prevent over-watering and conserve water resources.

By integrating a weather station into the smart irrigation system, the system can gather accurate and real-time data on temperature, humidity, wind speed, and rainfall. This data is crucial in understanding the external factors that impact plant water requirements. By considering the prevailing weather conditions, the system can make intelligent decisions and adjust the irrigation schedules accordingly. This ensures that the plants receive the appropriate amount of water based on both their internal moisture needs and the external environmental factors. As a result, water usage is optimized, and the overall health and growth of the plants are enhanced, promoting sustainable and efficient irrigation practices.

3.1.3. Water Fetching

The water fetching system is an integral part of the smart irrigation system, designed to draw water from a well or other water sources and provide a supplementary water supply for irrigation purposes. Its primary function is to reduce dependence on external water sources and promote self-sustainability within the system. Here's a more detailed explanation of the water fetching system:

- Water Source: The system is connected to a designated water source, typically a well or a reservoir, from which it can fetch water. This water source serves as an alternative or additional supply for irrigation, particularly in areas where access to municipal water or other external water sources is limited or unreliable.
- A water level switch sensor which is a device used to monitor the water level in a tank or reservoir. It consists of a float mechanism that rises and falls with the water level. When the water level reaches a certain point, the switch is triggered, providing a signal to indicate the water level status. This sensor is commonly used in various applications to prevent overflow or shortages and ensure efficient water management.
- Automated Water Fetching: The water fetching system is equipped with mechanisms and sensors that automate the process of drawing water from the designated source. It can be programmed to activate based on predefined triggers, such as low soil moisture levels or scheduled irrigation cycles. When triggered, the system initiates the water fetching process to ensure a constant supply of water for irrigation.
- Water Distribution: Once the water is fetched from the source, the system efficiently distributes it to the plants based on their specific watering needs. This is typically done through a network of irrigation pipes, valves, or drip irrigation systems. The water fetching system coordinates with other components of the smart irrigation system, such as the IoT sensors and control algorithms, to ensure precise and targeted water delivery to the plants.
- Efficient Water Usage: By incorporating a water fetching system, the smart irrigation system optimizes water usage by utilizing available water sources effectively. Instead of solely relying on external water supplies, the system can tap into the supplementary water source, reducing dependence on external resources. This promotes self-sustainability and ensures a continuous water supply for irrigation, even in areas with limited access to water.

  The inclusion of a water fetching system in the smart irrigation system contributes to efficient water management. It enhances the system's ability to provide adequate water to the plants while minimizing water wastage. By automating the process of drawing water and distributing it as needed, the system ensures that water is used efficiently and only when required, reducing the risk of over-irrigation. This not only conserves water resources but also promotes sustainable agricultural practices by enabling farmers to maximize water availability within their own land or property.

3.1.4. Solar Power system

The solar tracking system is a crucial component of the smart irrigation system that enhances its energy efficiency and ensures a continuous power supply. Here's a more detailed explanation of the solar tracking system:

- Solar Panels: The smart irrigation system is equipped with solar panels that convert sunlight into electrical energy. These panels are typically composed of photovoltaic cells that generate direct current (DC) electricity when exposed to sunlight.
- Solar Tracking Mechanism: The solar tracking system employs a mechanism that continuously adjusts the position and orientation of the solar panels throughout the day. This mechanism tracks the movement of the sun across the sky to ensure that the solar panels receive maximum sunlight exposure.
- Optimal Sunlight Exposure: By dynamically adjusting the position of the solar panels, the system maximizes their exposure to sunlight. This optimization allows the panels to capture the highest possible amount of solar energy throughout the day, leading to increased energy generation.
- Energy Generation and Battery Recharging: The electrical energy generated by the solar panels is used to power the smart irrigation system directly. Additionally, the excess energy is stored in a battery for later use. The battery serves as an energy reservoir, ensuring uninterrupted operation of the system, particularly during periods of low sunlight or at night.
- Energy Efficiency and Sustainability: The solar tracking system improves the overall energy efficiency of the smart irrigation system. By constantly adjusting the position of the solar panels, the system maximizes energy generation, reducing reliance on external power sources. This energy-efficient approach promotes sustainability by utilizing renewable energy and minimizing the carbon footprint associated with traditional power sources.

- Suitable for Remote Areas: The solar tracking system is particularly beneficial in areas with limited access to electricity. By harnessing solar energy, the system can operate independently of the electrical grid, making it suitable for remote locations or regions where grid connectivity is unreliable or nonexistent.

By incorporating a solar tracking system, the smart irrigation system optimizes energy generation from solar panels and ensures a continuous power supply. This sustainable approach reduces dependence on conventional energy sources, lowers operating costs, and enables the system to function efficiently in diverse environments. Additionally, the solar tracking system aligns with environmental conservation efforts by utilizing clean and renewable energy, contributing to a greener and more sustainable future.

3.1.5. Arduino Microcontroller

The Arduino microcontroller is a fundamental component of the smart irrigation system, acting as the central processing unit that enables intelligent control and decision-making. Here's a more detailed explanation of its role and functionality:

- Data Collection and Processing: The Arduino microcontroller is responsible for collecting data from the IoT sensors that measure crucial parameters such as soil moisture, temperature, and humidity. It also receives data from the weather station, which provides information on ambient conditions like temperature, humidity, wind speed, and rainfall. The microcontroller processes this data to gain insights into the irrigation requirements of the plants.
- Intelligent Control Algorithms: The Arduino microcontroller utilizes intelligent control algorithms to analyze the collected data and make informed decisions regarding irrigation schedules. By considering factors such as soil moisture levels, weather conditions, and plant requirements, the microcontroller can determine the optimal timing and duration of irrigation cycles. This intelligent control ensures that water is delivered only when needed, minimizing water waste.
- Irrigation Valve/Motor Control: The microcontroller is responsible for controlling the irrigation valves or motors that regulate the flow of water to the plants. Based on the analyzed data and irrigation schedule, the microcontroller signals the valves or motors to open or close, allowing water to be delivered to the plants in a precise and controlled

manner. This level of control helps to prevent over-watering and under-watering, ensuring that the plants receive the right amount of water for optimal growth.

- Water Waste Reduction and Efficiency: The precise control provided by the Arduino microcontroller contributes to minimizing water waste and improving irrigation efficiency. By delivering water only when required, based on real-time data and intelligent algorithms, the system optimizes water usage. This not only conserves water resources but also reduces costs associated with excess water consumption and enhances overall irrigation effectiveness.

By utilizing the Arduino microcontroller, the smart irrigation system achieves intelligent and efficient control over irrigation processes. The microcontroller's ability to collect, process, and analyze data, combined with its control over irrigation valves or motors, ensures that water is used judiciously and in accordance with plant needs. This helps to promote sustainable water management practices and facilitates healthier plant growth.

3.1.6. User interface and remote access

- The user interface and remote access capabilities of the smart irrigation system play a vital role in enabling users to conveniently control, monitor, and manage the system. Here's a more detailed explanation of this aspect:

- User-Friendly Mobile Interface: The smart irrigation system incorporates a user-friendly interface that allows farmers to control and monitor the system using their mobile phones via SMS. This interface is designed to provide a simple and intuitive experience that users can easily navigate. The interface is optimized for mobile phones, ensuring compatibility across various devices and operating systems.

- Control and Monitoring: Through SMS, users can control and adjust various aspects of the smart irrigation system. They can easily set irrigation schedules, specifying the frequency and duration of watering cycles. Users can also monitor real-time data from the IoT sensors, such as soil moisture levels, temperature, and humidity, providing them with valuable insights into the irrigation status and plant conditions.

- Convenient Access Anywhere: By leveraging SMS, users can access the smart irrigation system from anywhere without needing an internet connection. This remote access capability enables farmers, landscapers, or users to monitor and manage the system even when they are not physically present at the irrigation site. They can conveniently adjust irrigation schedules, initiate manual watering, or check the system's status on the go.

- Real-Time Notifications and Alerts: The system integrates real-time notifications and alerts, keeping users informed about the system's status and critical events. Users can receive instant alerts about low soil moisture levels, system malfunctions, or other important updates. This proactive notification system enables users to take immediate action and address any issues promptly, ensuring the optimal functioning of the irrigation system.

- Enhanced Convenience and Efficiency: The user interface and remote access capabilities enhance the overall convenience and efficiency of managing the smart irrigation system. Users no longer need to be physically present at the irrigation site to adjust or monitor the system. They can easily use their mobile phones to control irrigation schedules and monitor sensor data, saving time and effort.

3.2. Implementation

3.2.1 Water Fetching system

Water fetching and storage are vital components of any water management system. In many areas, water scarcity is a significant challenge, and reliable systems for water storage are essential to ensure that there is always enough water available for domestic or industrial use. One solution to this problem is using a water level sensor in the container and a motor pump in the well for fill-up. This system is designed to automate the process of water filling and provide real-time monitoring of the water levels in the storage containers. The water level sensor ensures that the container is filled to the optimal level, re- ducing water wastage, and ensuring that there is always enough water available for use. The motor pump in the well facilitates the efficient and rapid filling of the storage containers, which is particularly important during times of high wa- ter demand. The use of this technology can significantly improve the efficiency and reliability of water storage systems, ensuring that water resources are used optimally and sustainably over the long term.

Description

1. Power Supply: The first step is to connect the power supply to the Arduino board. The power supply can be a wall adapter, a battery, or a solar panel depending on the application.
2. Sensors: The next step is to connect the sensors that measure the water level in the well. These sensors can be ultrasonic, pressure, or float sensors. The connections will depend on the type of sensor being used, but in general, the sensor will have three wires: power, ground, and signal. The power and ground wires are connected to the Arduino's 5V and GND pins respectively, while the signal wire is connected to one of the analog input pins of the Arduino.

3. Pump Control: The pump control circuit is used to turn on and off the pump based on the water level measured by the sensors. This circuit consists of a relay module that is connected to the Arduino board. The relay module has three wires: signal,power, and ground. The signal wire is connected to one of the digital output pins of the Arduino, while the power and ground wires are connected to the power supply.

4. Pump: The pump is connected to the relay module. The relay module has two output terminals that are connected to the pump. These terminals are normally open, meaning that when the relay is off, the circuit is open and the pump is not powered. When the relay is on, the circuit is closed and the pump is powered.

5. Programming: The last step is to program the Arduino board to read the sensor data and control the pump accordingly. The code can be written using the Arduino IDE, and can be uploaded to the board via a USB cable. The code will define the sensor input pin, the relay output pin, and the threshold values for turning on and off the pump.

Once all these connections are made and the code is uploaded to the Arduino board, the water well system will be able to automatically pump water from the well based on the water level measured by the sensors.

Water Pump Circuit diagram

The water pump is connected to a motor driver, which then connects to the analog pin of an Arduino microcontroller. The sensors, including soil moisture sensors, temperature sensors, humidity sensors, and PIR sensors, are appropriately connected to the Arduino using suitable cables. The Arduino sketch, containing the program code, is uploaded to the microcontroller using the Arduino IDE. System settings, such as the irrigation schedule and threshold values for soil moisture and ambient conditions, are configured. It is illustrated in Figure 3.2 . Thorough testing is conducted to ensure the proper functioning of the system and validate its ability to make intelligent decisions based on sensor data for efficient and precise watering schedules.

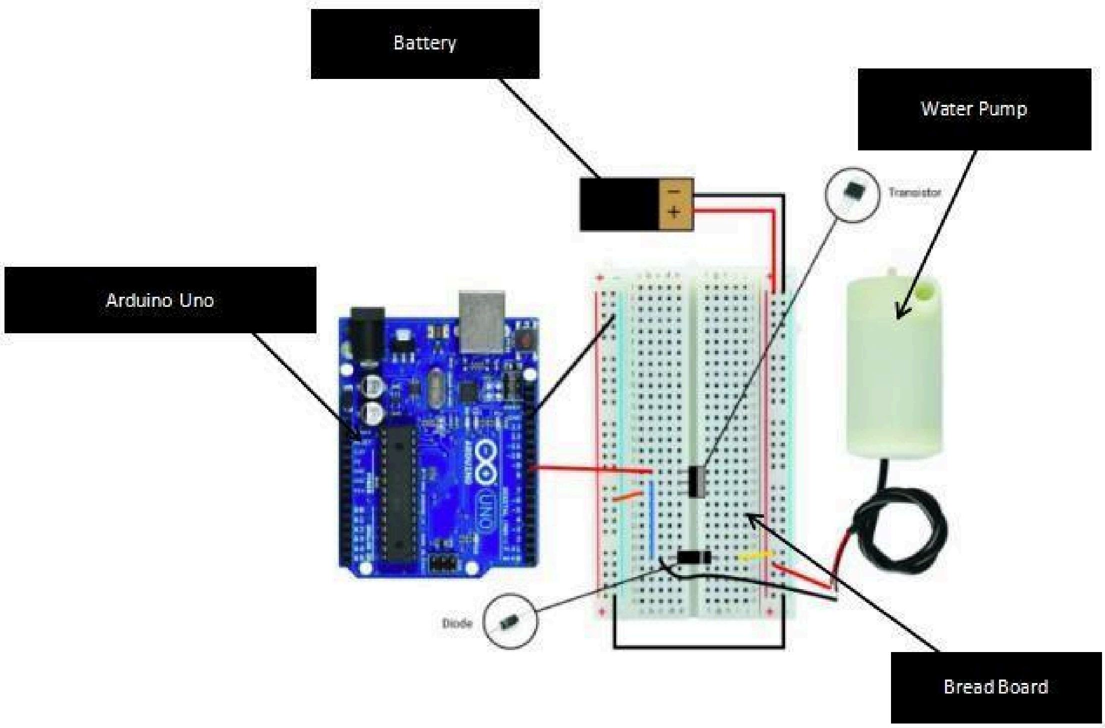

Figure 3.3: water pump connection

Table 3.1: Motor pump specifications

Device Name	Model	Specifications

Motor pump	DC12V SUBMERSIBLE PUMP	• Color: White • Material: ABS(Acrylonitrile Butadiene Styrene) + Stainless Steel • Size: Approx. 80 x 48 x 63mm/3.15 x 1.89 x 2.48" • Pump Inlet Diameter: 16mm(Outer), 12mm(Inner) • Pump Outlet Diameter: 12mm(Outer), 6.9mm(Inner) • Inlet/Outlet: 1/2" male thread • Voltage: 6-12V DC • Maximum Rated Current: 1.2A • Power:16.8W • Max Flow Rate: 700 L/H • Max Water Head: 5m • Max Circulating Water Temperature: 60°C

Level Switch Sensor

The connection of the level switch sensor is illustrated in Figure 3.3 and is done by the following steps: Connection of the VCC pin of the level switch sensor to the 5V pin on the Arduino for power supply. Connect the GND pin of the level switch sensor to the GND pin on the Arduino to establish the ground connection. Next, connect the signal pin of the level switch sensor to a digital pin on the Arduino, such as pin 2, to receive the sensor data. Open the Arduino IDE and create a new sketch. In the setup function, initialize the digital pin as an input using the pinMode function, for example: pinMode(2, INPUT). In the loop function, use the digitalRead function to read the value of the digital pin and store it in a variable (e.g., int sensorValue = digitalRead(2)). If the sensor value is HIGH, it indicates that the water level is below the sensor, while a LOW value indicates that the water level is above the sensor. For debugging purposes, utilize the Serial.println function to print the sensor value to the Serial

Monitor (e.g., Serial.println(sensorValue)). Upload the sketch to the Arduino board and monitor the sensor.

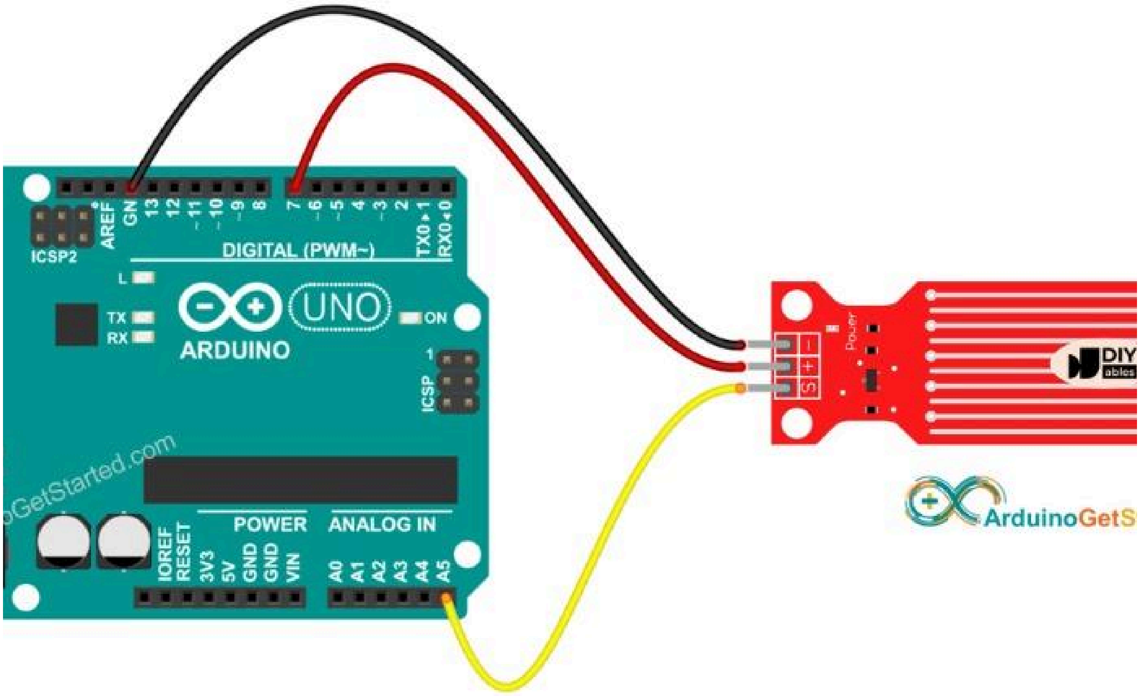

Figure 3.4: Water Level sensor

Table 3.2: Water Level sensor specifications

Device Name	Model	Specifications
Water level sensor	WATER LEVEL SENSOR FLOAT SWITCH	● Contract rating(Max):10W Switching; Voltage(Max): 110VDC; Switching Current(Max): 0.5A Breakdown; Voltage(Max): 220VDC Carry; Current(Max): 1.0A Contract; Resistance(Max): 100 OHM Temperature; Rating: -30~+125°C; ● Cable length：400MM; ● Material:Stainless Steel

3.2.2. Irrigation System

The irrigation system implementation requires components that include:

Arduino Uno

The Arduino Uno in Figure 3.4 is a microcontroller board based on the ATmega328 micro-controller. It is a widely used platform for building electronic projects, and it is particularly popular among hobbyists and DIY enthusiasts. In a smart irrigation system, the Arduino Uno could be used as the central processing unit that controls the system. It could read data from sensors (such as moisture sensors and weather sensors), make decisions based on that data, and control actuators (such as watering valves) to adjust the watering schedule. The Arduino Uno could also be programmed to communicate with a smartphone or other device to allow remote control of the system. Its specifications is provided in Table 3.3.

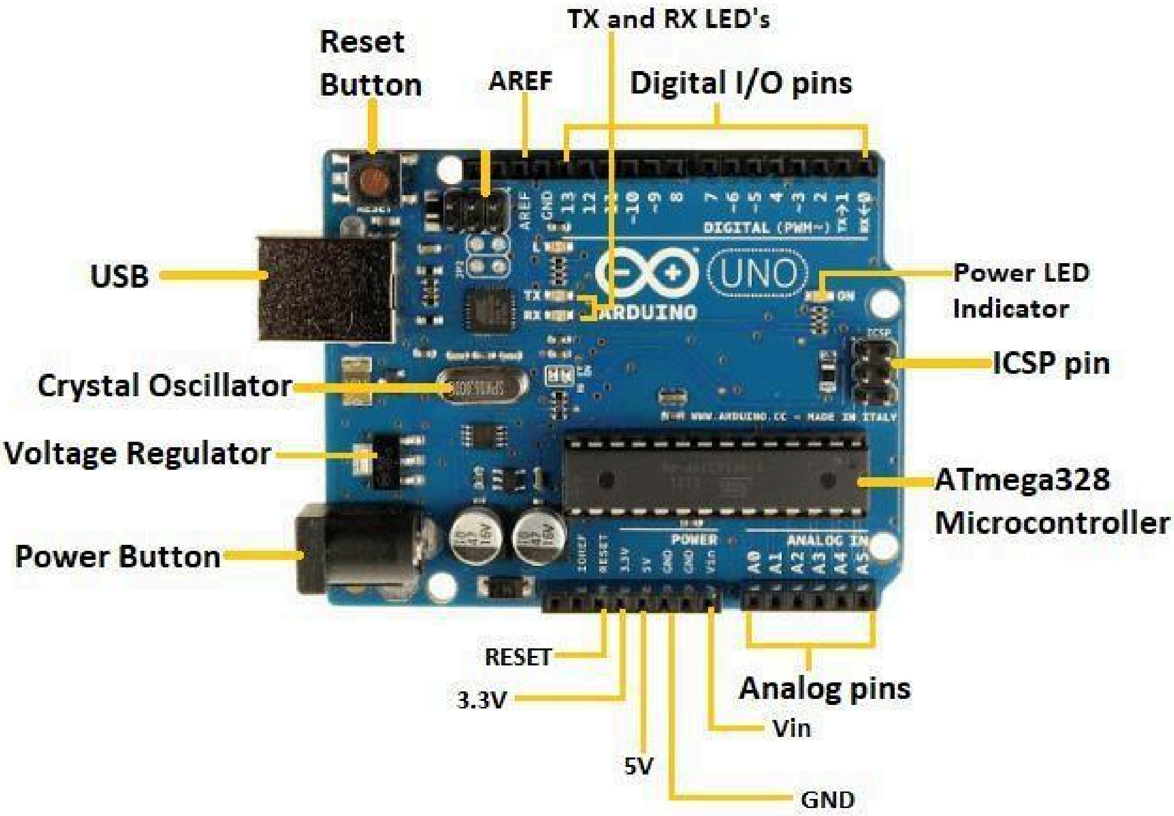

Figure 3.5: Arduino Uno

Table 3.3: Arduino uno specifications

Device Name	Model	Specifications
Microcontroller	ARDUINO UNO R3 (SMD ATMEGA328 IC)	• Microcontroller: ATmega328P • Operating Voltage: 5V • Input Voltage (recommended): 7-12V • Input Voltage (limit): 6-20V • Digital I/O Pins: 14 (of which 6 provide PWM output) • PWM Digital I/O Pins: 6 • Analog Input Pins: 6 • DC Current per I/O Pin: 20 mA • DC Current for 3.3V Pin: 50 mA • Flash Memory: 32 KB (ATmega328P) of which 0.5 KB used by bootloader • SRAM: 2 KB (ATmega328P) • EEPROM: 1 KB (ATmega328P) • Clock Speed: 16 MHz • LED_BUILTIN: 13 • Length: 68.6 mm • Width: 53.4 mm • Weight: 25 g

Soil moisture

A soil moisture sensor is a device that is used to measure the water content in soil. It typically consists of two electrodes that are placed in the soil, and the sensor measures the electrical resistance between the electrodes to determine the moisture level. Soil moisture sensors can be used in a variety of applications, including agriculture, landscaping, and home gardening. In a smart irrigation system, a soil moisture sensor can be used to monitor the moisture levels in the soil and automatically adjust the watering schedule to ensure that plants are receiving the optimal amount of water.

Circuit diagram

The connection of the sensor with an amplifier circuit to an Arduino for analog data is showed in Figure 3.5. the first step is to use hook-up wires to connect the two pins from the sensor to their corresponding pins on the amplifier circuit. Make sure the connections are secure and reliable. Next, connect the Vcc (power supply) pin from the amplifier to the 3.3V pin on the Arduino, providing power to the circuit. Connect the Gnd (ground) pin from the amplifier to the Gnd pin on the Arduino to establish a common ground reference. Finally, connect the Analog Data Pin from the amplifier circuit to the A0 pin on the Arduino, as you are interested in reading analog data from the sensor. This will enable the Arduino to receive the analog readings from the sensor via the amplifier circuit. The specifications of this sensor is given in Table 3.4.

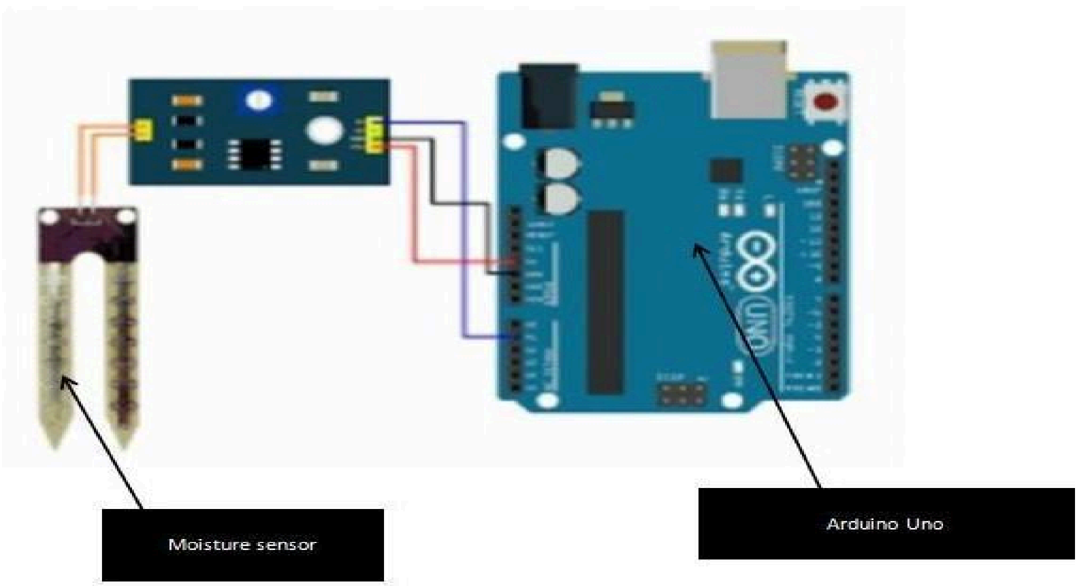

Figure 3.6: Soil Moisture Sensor

Table 3.4: Soil Moisture sensor

Device Name	Model	Specifications
Soil Moisture sensor	LM393 Sensor	• Operating voltage: 3.3V~5V; • Dual output mode, analog output more accurate; • A fixed bolt hole for easy installation • With power indicator (red) and digital switching output indicator (green); • Having LM393 comparator chip, stable • Panel PCB Dimension: Approx.3cm x 1.5cm; • Soil Probe Dimension: Approx. 6cm x 3cm; • Cable Length: Approx.21cm

Temperature and humidity sensor

A temperature and humidity sensor is a device that is used to measure both the temperature and the humidity (or moisture content) of the air. It is commonly used in a variety of applications, including weather forecasting, climate control, and industrial process control.

Temperature and humidity sensors (Figure 3.6) typically consist of a thermistor (a temperature- sensitive resistor) and a humidity sensor, which can be a capacitive, resistive, or optical sensor. The thermistor measures the temperature of the air, while the humidity sensor measures the moisture content of the air. The sensor send this data to a microcontroller or other device, which can then use the information to control various functions, such as adjusting the temperature of a building or activating a humidifier.

In a smart irrigation system, a temperature and humidity sensor can be used to monitor the weather conditions and adjust the watering schedule accordingly. For example, if the air is very humid, the plants may not need as much water, so the watering schedule can be adjusted accordingly. Similarly, if the temperature is very high, the plants may need more water to stay hydrated, so the watering schedule can be increased.

Circuit diagram

The DHT11 sensor is designed to measure and provide humidity and temperature values through a single wire in a serial format. It can accurately measure relative humidity within a range of 20% to 90% and temperature in the range of 0°C to 50°C as mentioned in Table 3.5, both represented with appropriate units. The sensor is equipped with four pins, out of which one is specifically designated for data communication. By encoding pulses with different TON (pulse duration of logic 1) and TOFF (pulse duration of logic 0), the sensor transmits data as logic 1 or logic 0, as well as start and end pulses, allowing for proper decoding and retrieval of the measured values. This compact sensor provides a convenient solution for obtaining reliable humidity and temperature readings in various applications.

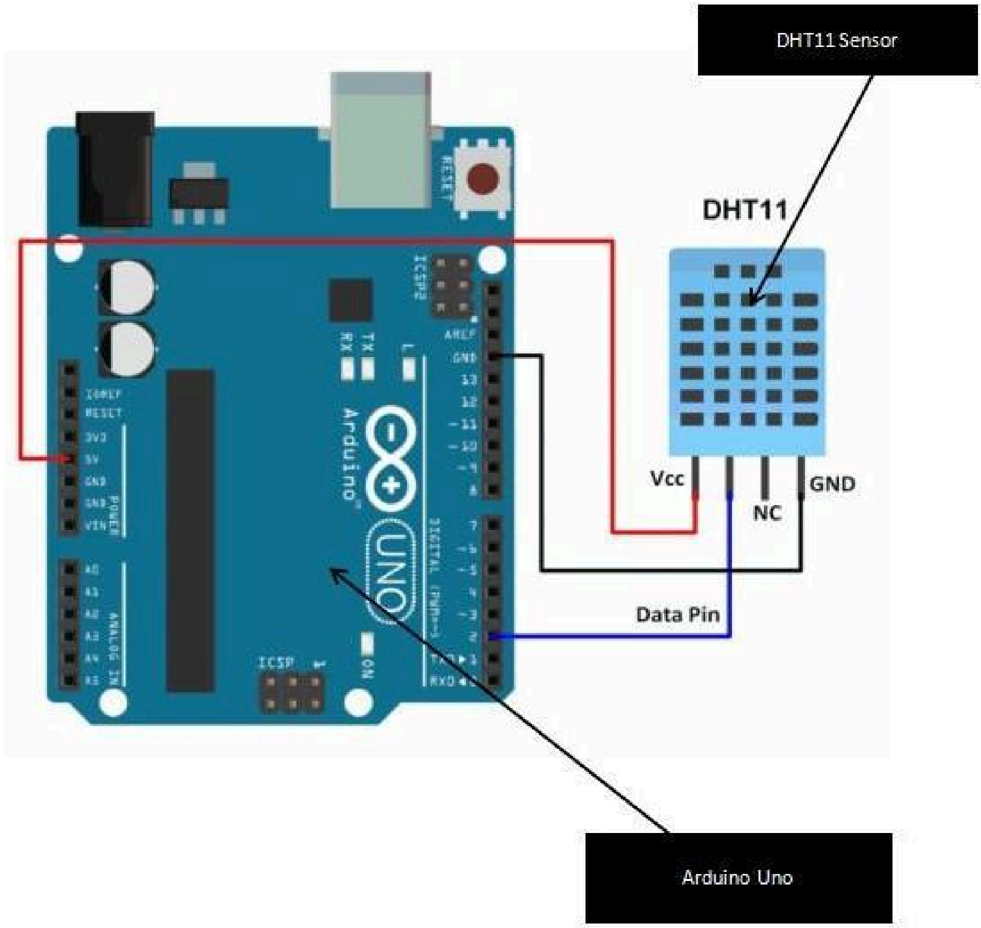

Figure 3.7: DHT11

Table 3.5: Temperature & Humidity sensor

Device Name	Model	Specifications
Temperature & Humidity sensor	DHT 11	• Operating Voltage: 3.5V to 5.5V • Operating current: 0.3mA (measuring) 60uA (standby) • Output: Serial data • Temperature Range: 0°C to 50°C • Humidity Range: 20% to 90% • Resolution: Temperature and Humidity both are 16-bit • Accuracy: ±2°C and ±5%RH

PIR sensor

A PIR (passive infrared) sensor is a device that is used to detect the presence of a moving object, such as a human or an animal. It works by detecting the infrared radiation (heat) that is emitted by the object. It consist of a pyro- electric element, which is a material that generates an electric charge when it is exposed to infrared radiation, and a number of other components that are used to amplify and filter the signal. When a moving object passes in front of the sensor, the pyroelectric element detects the change in infrared radiation and generates an electrical signal. This signal can then be used to trigger an alarm, turn on a light, or perform some other action.

In this system, a PIR sensor is used to detect the presence of humans or animals in a garden or landscaped area, and adjust the watering schedule accordingly. So if the sensor detects movement, the system will reduce the watering schedule to avoid overwatering, or increase the watering schedule to ensure that the plants have enough water.

Circuit diagram

The connection of a PIR sensor to an Arduino(Figure 3.7), has been done by following these steps: The Vcc pin of the PIR sensor is connected to the positive terminal (5V) of the Arduino, providing it with power supply. Next, the Gnd pin of the PIR sensor is connected to one ground pin of the Arduino to establish a common ground reference. Finally, the Out pin of the PIR sensor to pin number 7 of the Arduino, allowing the Arduino to receive and process the sensor's output. This connection enables the Arduino to detect motion and presence based on the infrared signals sensed by the PIR sensor, making it useful for applications such as security systems, automatic lighting, and occupancy detection. The specifications of this sensor is provided in Table 3.6.

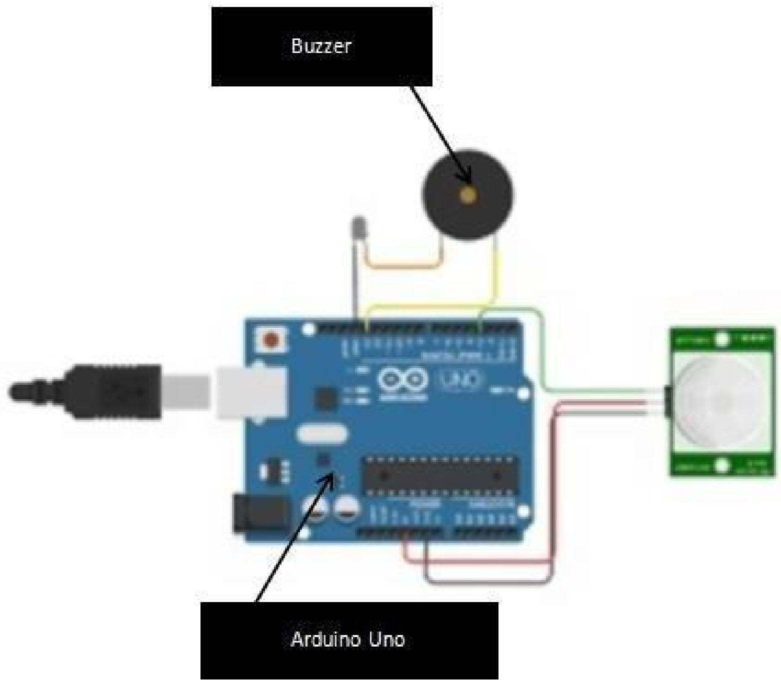

Figure 3.8: PIR Sensor

Table 3.6: Motion detection

Device Name	Model	Specifications
Motion detection	HC-SR501	● HC-SR501 Human Sensor Module Pyroelectric Infrared. Product Type: HC--SR501 Body Sensor Module ● Operating voltage range: DC 4.5-20V ● Quiescent Current: <50uA ● Level output: High 3.3 V /Low 0V ● Trigger: L cannot be repeated trigger/H can be repeated trigger(Default repeated trigger)

Display Monitor LCD Display

An LCD (liquid crystal display) display is a type of display that uses liquid crystals to produce an image(Figure 3.8). It is commonly used in a variety of electronic devices, including smartphones, laptops, televisions, and digital clocks.In a smart irrigation system, an LCD display is used to display information about the system, such as the current moisture levels in the soil, the weather conditions, and the watering schedule. It displays alerts or messages, such as a warning if the system detects a problem.

Circuit diagram

LCD (Liquid Crystal Display) is connected to Arduino by : connecting the GND (ground) pin of the LCD to the GND pin of the Arduino, establishing a common ground reference. Next, connect the VCC pin of the LCD to the 5V pin of the Arduino, providing power to the LCD module. The SDA (Serial Data Line) pin of the LCD is connected to the A3 pin of the Arduino, enabling data communication between the LCD and Arduino. Similarly, connect the SCL (Serial Clock Line) pin of the LCD to the A5 pin of the Arduino. This connection allows the Arduino to send data and commands to the LCD for displaying information. With these connections, the Arduino can effectively control and interact with the LCD display, enabling the creation of user interfaces and visual output in various projects. The specifications of the model used is showed in Table 3.7.

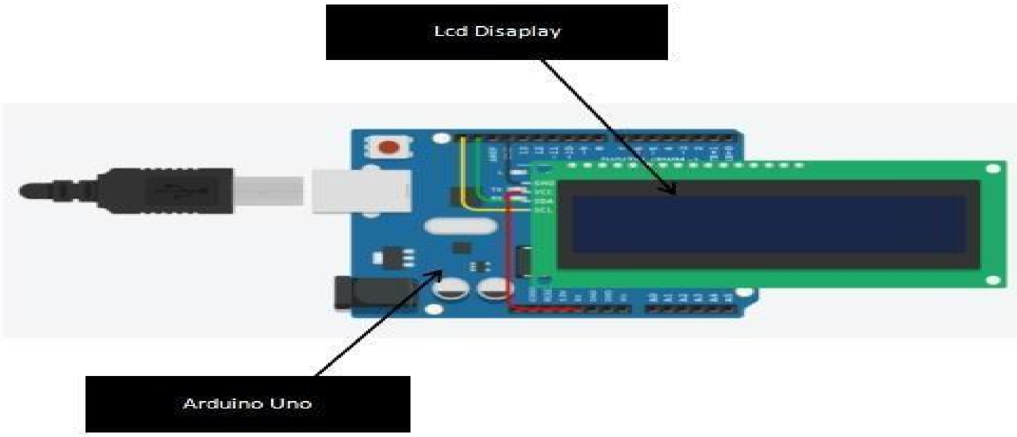

Figure 3.9: LCD Display

Table 3.7: LCD Display

Device Name	Model	Specifications
Display	LCD1602+I2C LCD 1602 MODULE BLUE SCREEN	• Size: 80.1mm*36mm • Logic working voltage: (Vdd)+4.8V~+5.2V • Display: white on blue/black on yellow • LCD drive voltage: (Vdd-Vo)+5V • Working temperature: (Ta)-20°C~+70°C (wide temperature) • Storage temperature: (Tsto) - 30°C~+80°C (wide temperature) • Working current: (except backlight) 1.7mA (max) • Working current: (backlight) 24.0mA (max)

Water pump

The motor pump is connected to the motor driver module, which is in turn connected to the Arduino Uno as in Figure 3.9. Power is supplied to the motor driver module separately. The motor driver module receives commands from the Arduino Uno to control the motor pump's direction and speed. The Arduino Uno acts as the controller, sending signals to the motor driver module based on programmed instructions. The motor driver module interprets these signals and controls the motor pump accordingly.

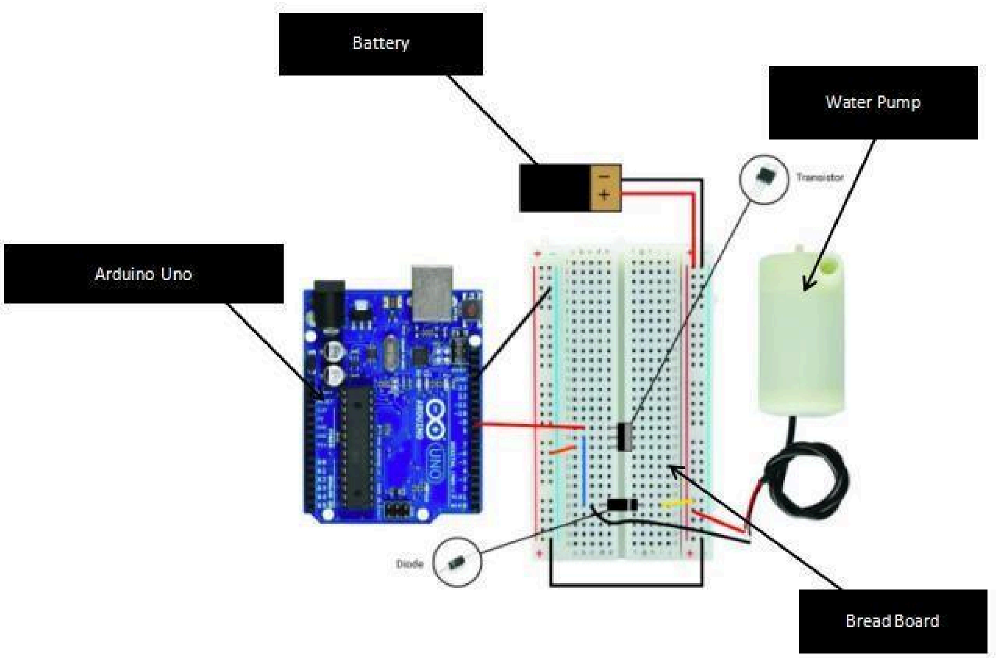

Figure 3.10: motor pump circuit connection

Table 3.8: Water pump circuit connection

Device Name	Model	Specifications
Motor pump	DC12V SUBMERSIBLE PUMP	• Color: Black • Material: ABS(Acrylonitrile Butadiene Styrene) + Stainless Steel • Size: Approx. 80 x 48 x 63mm/3.15 x 1.89 x 2.48" • Pump Inlet Diameter: 16mm(Outer), 12mm(Inner) • Pump Outlet Diameter: 12mm(Outer), 6.9mm(Inner) • Inlet/Outlet: 1/2" male thread • Voltage: 6-12V DC • Maximum Rated Current: 1.2A • Power:16.8W • Max Flow Rate: 700 L/H • Max Water Head: 5m • Max Circulating Water Temperature: 60°C

3.2.3. Solar Power System

Introduction

The implementation of solar tracking systems in smart irrigation projects has revolutionized the field of renewable energy, providing efficient and sustainable solutions to energy needs. In these systems, solar tracking systems are used to power irrigation pumps and equipment, reducing energy costs, and carbon emis- sions. However, one challenge with using solar energy is that it is intermittent, and energy storage systems are necessary to ensure continuous energy supply, particularly during periods of low sunlight.

To address this challenge, batteries are used to store the excess solar energy generated during periods of high sunlight. The implementation of solar tracking systems ensures that the solar panels generate the maximum amount of energy, optimizing battery charging efficiency. The use of batteries to store solar energy ensures that the irrigation system can operate optimally even during periods of low sunlight or at night.

Description

Building a solar tracking system requires several components to ensure the effi- cient and optimal functioning of the system. Here is a description of the main components necessary to build a solar tracking system:

- Solar panel: A single solar panel is used to convert sunlight into electrical energy. It is the primary source of power for the system with specifications in Table 3.9 and illustrated in Figure 3.10.

Table 3.9: Solar panel specifications

Device Name	Model	Specifications
Solar panel	5V 1W SOLAR PANEL 105X54 MM	• Material: Polycrystalline • Net Weight: 20g; • Main Color: Black; • Voltage: 5V • Dimension: 105x54mm • Power: 1W (+-2%) • Package Content: 1 x Solar Pane

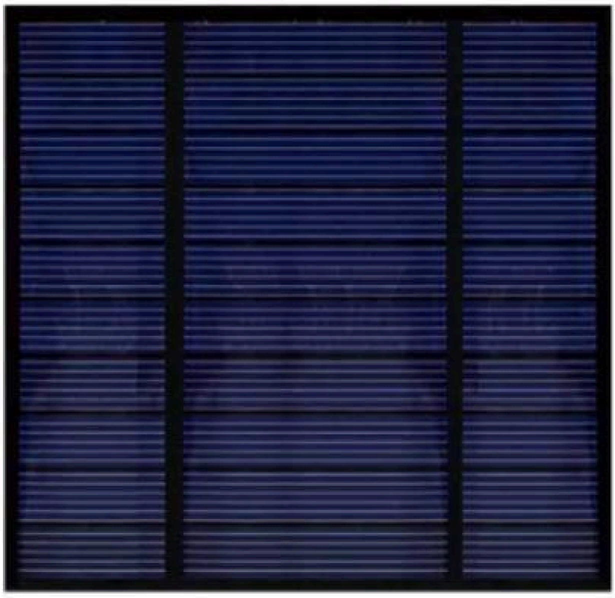

Figure 3.11: Solar Panel

- Servo motor: The servo motor is used to rotate the solar panel to track the sun's movement. The motor is controlled by the microcontroller (Figure 3.11) and ensures that the solar panel is always perpendicular to the sun's rays, maximizing energy output with specifications in Table 3.10.

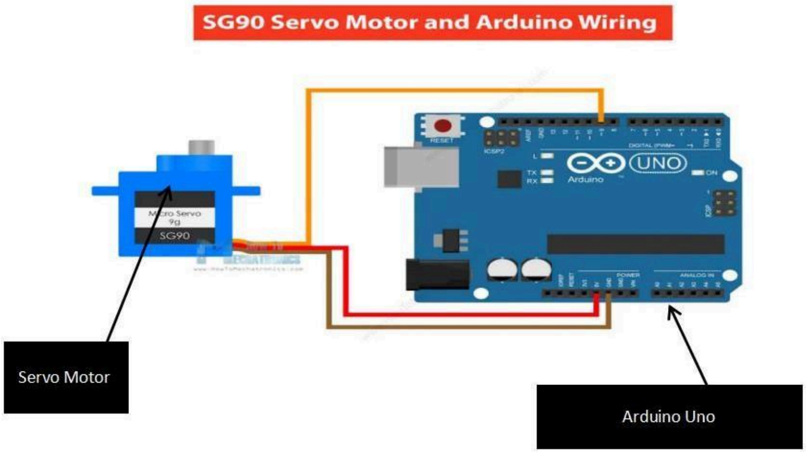

Figure 3.12: SG90 Servo Motor and Arduino Wiring

Table 3.10: Servo motor specifications

Device Name	Model	Specifications
Servo motor	5v DC servo motor	• Weight : 9 g • Size : 22 x 11.5 x 27 mm Operating Speed (4.8V no load): 0.12sec/60 degrees • Stall Torque (4.8V): 17.5oz/in (1.2 kg/cm) • Temperature Range: -30 to +60 Degree C • Dead Band Width: 7usec Operating Voltage:3.0-7.2 Volts

- LDR sensor: The LDR sensor(Figure 3.12) is used to detect the amount of sunlight and determine the solar panel's position. It provides feedback to the microcontroller to adjust the position of the servo motor accordingly. Its specifications is given in Table 3.11.

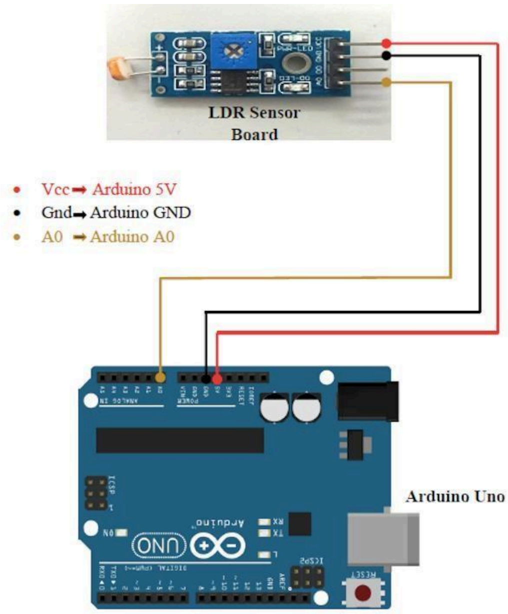

Figure 3.13: LDR sensor Board

Table 3.11: LDR sensor specifications

Device Name	Model	Specifications
Light detection sensor	LDR LIGHT SENSOR MODULE	• Can detect ambient brightness and light intensity • Adjustable sensitivity (via blue digital potentiometer adjustment) • Operating voltage 3.3V-5V • Output Type Digital switching outputs (0 and 1) -D0 • With fixed bolt hole for easy installation • Power indicator (red) and the digital switch output indicator (green) • Using LM393 comparator chip, stable

- Microcontroller: The microcontroller is responsible for controlling the servo motor and receiving feedback from the LDR sensor. It calculates the sun's posi- tion based on the LDR sensor readings and sends commands to the servo motor to adjust the solar panel's position.

The above components has been mounted on a sturdy structure to support the solar panel and protect the system from the elements.

3.2.4. Monitoring system

A monitoring system is a crucial component of an IoT-based smart irrigation project, and the Blynk app offers a convenient way to implement it. This system allows users to monitor their irrigation system using a smartphone, tablet, or computer, providing a more efficient and convenient way to manage their irrigation system.

The monitoring system setup involves the utilization of various components, including soil moisture sensors, weather condition sensors, and other relevant parameter sensors. These sensors are connected to a microcontroller or single-board computer, such as Arduino or Raspberry Pi. Data from the sensors is collected by the microcontroller or single-board computer and transmitted to the Blynk cloud-based platform.Users can then access the platform using the Blynk app, which provides real- time data on the irrigation system's status. With the app, users can view the current soil moisture levels, weather conditions, and other relevant data. They can also receive alerts and notifications about the system's status, such as low water levels or pump malfunctions, which helps them prevent crop damage and ensure the system is functioning optimally. The Blynk platform can also generate reports and analytics to help users optimize water usage and reduce waste, enabling them to make more informed decisions about their irrigation system.

Overall, the implementation of a monitoring system for this project using the Blynk app is facilitated in a convenient and effective manner. Remote access to data is enabled, resulting in enhanced efficiency and effectiveness of the irrigation system. This leads to time and cost savings while enabling farmers to make informed decisions regarding water usage. Attention should be given to ensure the system's reliability and security through meticulous implementation. Additionally, users should be provided with sufficient training and support to optimize their utilization of the system.

Chapter 4

4.1. Results

The experimental setup for this system comprises several components as illustrated in Figure 4.1. At the center of the setup is an Arduino Uno microcontroller, which acts as the control hub for the system. Surrounding the Arduino are various IoT sensors, including soil moisture sensors, temperature sensors, humidity sensors, and PIR (Passive Infrared) sensors. These sensors are strategically placed to collect real-time data on soil moisture levels, ambient temperature, atmospheric humidity, and the presence of living organisms. The Arduino communicates with these sensors to gather data, process it, and make intelligent decisions for efficient irrigation scheduling.

To power the system, a Li-ion battery is utilized, providing a portable and reliable power source. The solar tracking system, equipped with a potentiometer (pot), enables the system to track the movement of the sun and optimize solar energy capture throughout the day. This helps to recharge the Li-ion battery and sustain the system's operation without relying solely on grid electricity.

The testing setup includes pots filled with soil, simulating real-world plant and lawn environments. The soil is carefully monitored using the soil moisture sensors, ensuring accurate measurement of water content and enabling the system to determine precise watering requirements. The integrated PIR sensors detect any movement or heat signatures within the test area, preventing accidental irrigation when humans or animals are present.

Overall, this experimental setup showcases the integration of IoT technology, Arduino Uno, various sensors, Li-ion battery, and solar tracking system. It enables the development and testing of a smart irrigation system that optimizes water usage, promotes plant growth, and enhances water resource management in an intelligent and efficient manner.

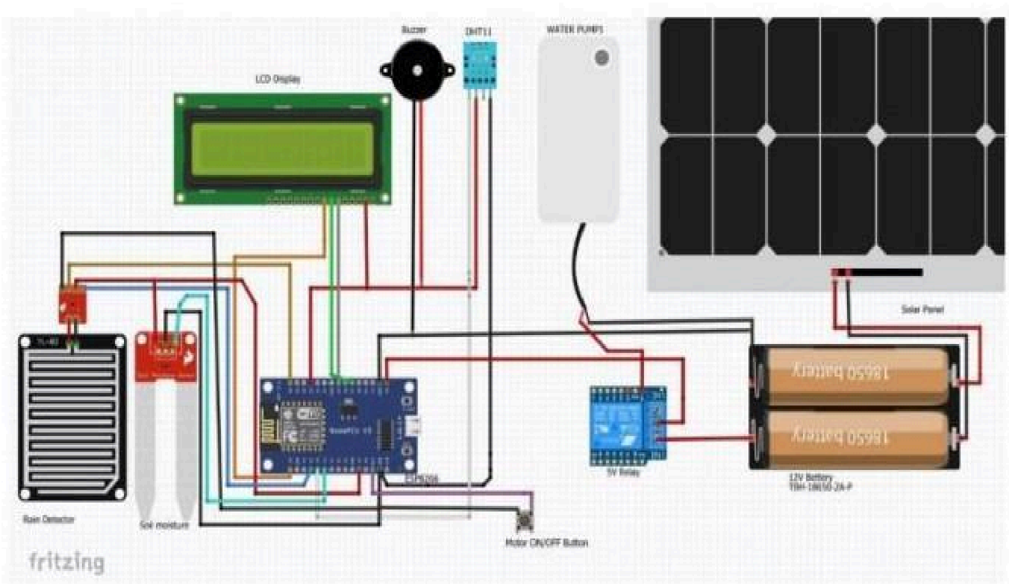

Figure 4.1: complete setup

4.1.1 Experiment 1: Water Fetching test

The smart irrigation system incorporates a water fetching system, which plays a crucial role in ensuring an adequate water supply for irrigation. This system comprises a storage unit positioned at the surface level and utilizes a centrifugal pump to collect water from underground sources as shown in Figure 4.2.

To initiate the water fetching process, the centrifugal pump is activated, drawing water from the underground source and delivering it to the storage unit. The system continuously monitors the water level in the storage unit using float switch sensor. Once the desired water level is detected, the control algorithm instructs the pump to stop, ensuring that the storage unit is not overfilled. As the irrigation process begins and water is utilized from the storage unit, the water level gradually decreases. When the water level falls below a predefined threshold, indicating that the available water is insufficient for irrigation, the control algorithm automatically triggers the pump to start. The pump draws water from the underground source and feeds it into the storage unit until the desired water level is achieved.

This comprehensive water fetching system ensures a sustainable water supply for irrigation. By collecting water from underground sources, it reduces dependence on external water sources and promotes self-sustainability. The use of a centrifugal pump allows for efficient water transfer, ensuring an adequate supply for irrigation needs. Moreover, the integration of sensors or float switches enables precise monitoring of the water level, preventing both overfilling and water shortages.

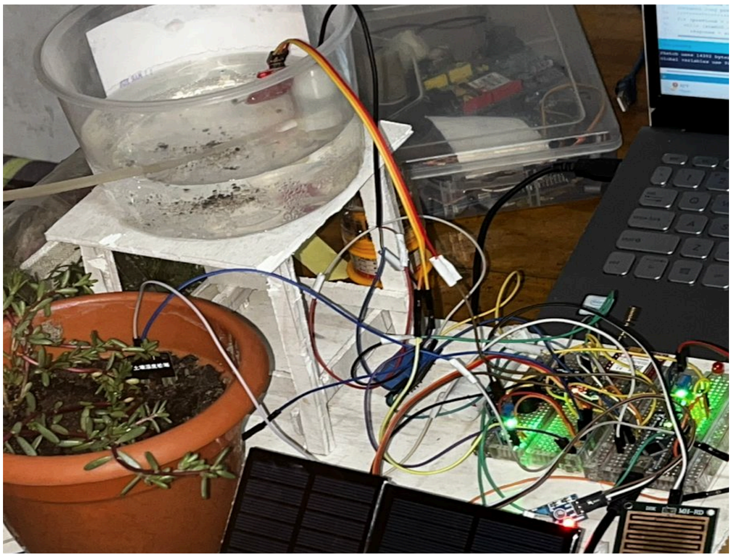

Figure 4.2: Water Fetching system

4.1.2 Experiment 2: Dry soil

In the conducted test the system employed two soil moisture sensors in contact with the soil, aiming to initiate irrigation when the soil moisture level was low and halt irrigation once the soil became sufficiently moist. The user interface app, developed using the Blynk platform, provided real-time data on the soil moisture level(Figure 4.3).

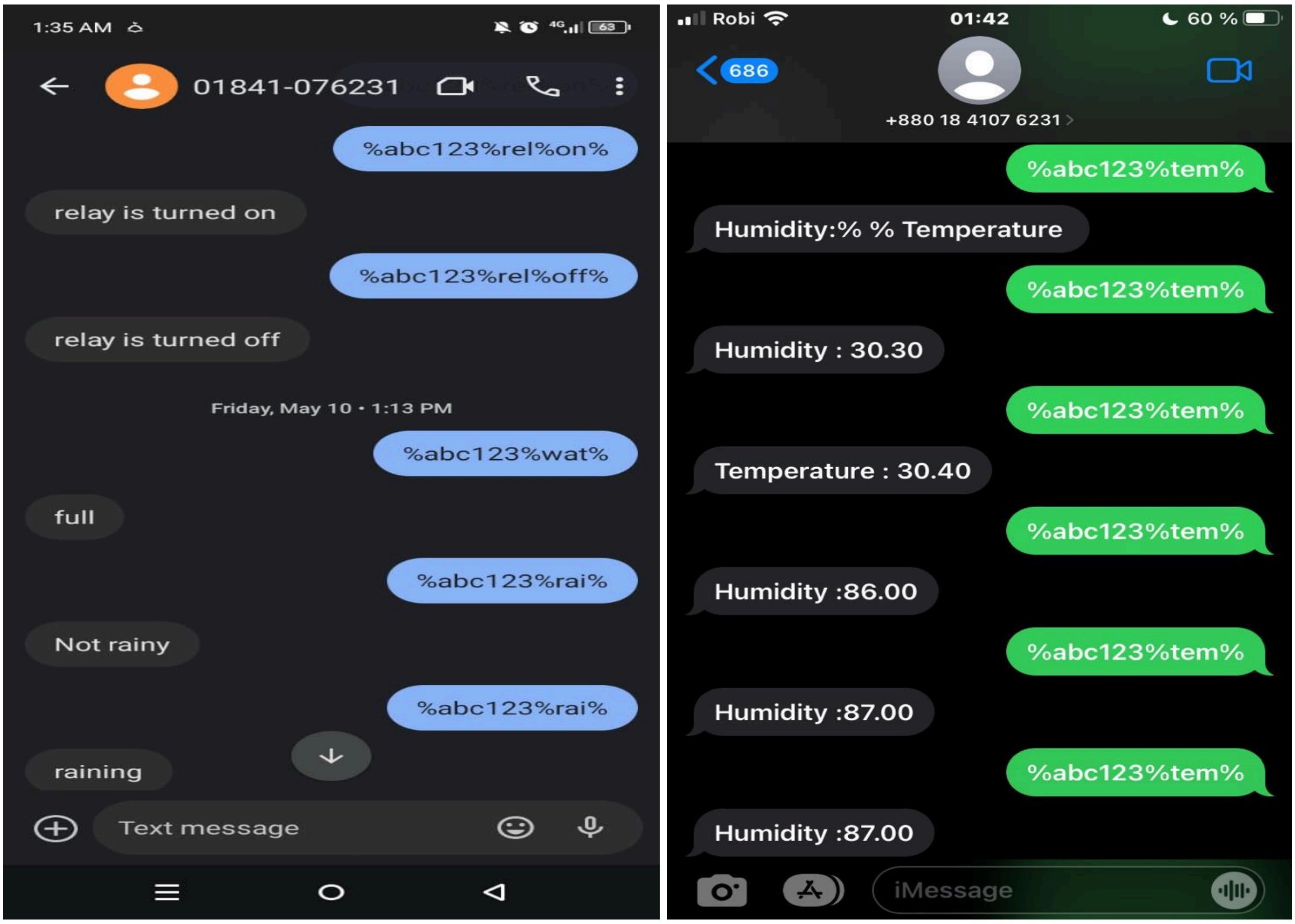

Figure 4.3: SMS command from a mobile

During the test, the soil moisture sensors continuously monitored the moisture level, and upon detecting a level below a predefined threshold, they triggered the activation of the pump, initiating the irrigation process. Simultaneously, the user received an alert notification through the GSM, notifying them that the pump was on and irrigation had started.

The irrigation process continued until the soil moisture level reached the desired moisture content. The control algorithm, monitoring the real-time readings from the soil moisture sensors, signaled the pump to stop, thereby ceasing the irrigation process. The user interface app promptly updated to display the current soil moisture level, indicating the cessation of irrigation. The information given by the GSM is summarized in Table 4.1.

Table 4.1: dry soil readings

Moisture Level	Soil moisture sensor readings	Pump Status	Temperature	Humidity
Dry soil	9.6 %	ON	26.5	23.7%
Semi-dry soil	47.4%	ON	25.9	36.6%

Throughout the test, the user interface app provided a comprehensive and accessible platform for users to monitor the soil moisture level and other relevant data. This information empowered users to make data-driven decisions regarding irrigation scheduling and water management. By leveraging real-time data and intelligent control algorithms, the IoT-based smart irrigation system showcased its efficiency in automating irrigation, conserving water resources, and minimizing manual intervention.

The integration of the Blynk platform in the user interface app enhanced the user experience by delivering real-time updates and alerts about the irrigation process. Users could conveniently access the app on their smartphones or tablets, enabling on-the-go monitoring and control of the system.The readings from Blynk app shows.

4.1.3 Experiment 3: Wet soil

In another test scenario, the IoT-based smart irrigation system was deployed in an area with initially wet soil. The system incorporated two soil moisture sensors that were in contact with the soil, with the objective of conserving water by avoiding unnecessary irrigation. The user interface app, developed using the Blynk platform, provided real-time updates on the soil moisture level, allowing users to monitor the irrigation process.

During the test, the soil moisture sensors continuously monitored the moisture level of the soil. Since the soil was initially wet, the sensors detected a high moisture level above the predefined threshold. As a result, the control algorithm did not activate the pump, ensuring that no irrigation was initiated. The user interface app displayed the current soil moisture level, indicating that irrigation was not required at that time. The data is grouped in Table 4.2.

Table 4.2: Wet soil readings

Moisture Level	Soil moisture sensor readings	Pump Status	Temperature	Humidity
Wet Soil	83.4%	OFF	22.6	74%
Semi-wet soil	63.7%	OFF	23.8	63.7%

As time progressed, the soil naturally dried out due to evaporation or plant uptake of water. When the soil moisture level dropped below the predefined threshold, the sensors detected the change and triggered the activation of the pump to start the irrigation process. The user received an alert notification through the Blynk app, indicating that the pump had been activated and irrigation was underway.

The irrigation process continued until the soil moisture level reached the desired moisture content. The control algorithm monitored the real-time readings from the soil moisture sensors and detected that the soil had become adequately moist. Consequently, the control algorithm signaled the pump to stop, halting the irrigation process. The user interface app promptly updated to display the current soil moisture level, indicating the cessation of irrigation.

Throughout the test, the user interface app provided real-time data and notifications, enabling users to stay informed about the irrigation process and make informed decisions regarding water management. By leveraging the IoT technology and intelligent control algorithms, the smart irrigation system effectively optimized irrigation practices, conserving water resources and minimizing unnecessary irrigation for wet soil conditions.

The integration in the user interface ensured a user-friendly experience, enabling users to conveniently monitor and control the system on their smartphones or tablets. The app provided insights into the current soil moisture level and allowed users to adjust irrigation schedules or settings as needed, promoting efficient water management practices. The Figure 4.4 is illustrating the output gotten during the experiment.

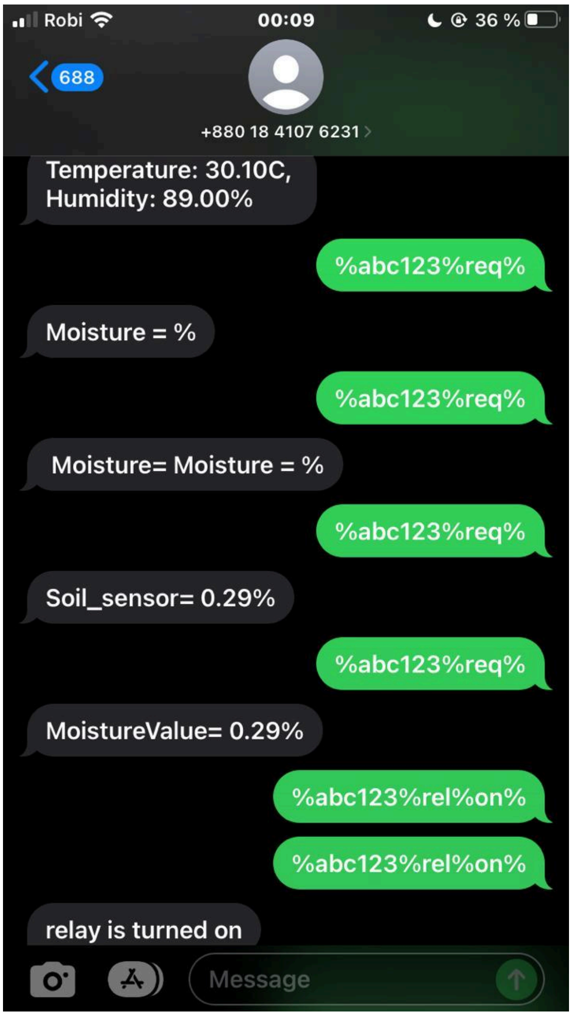

Figure 4.4: Soil Moisture reading for wet soil

4.1.4 Experiment 4: Solar System

The solar system (Figure 4.5) is integrated into the smart irrigation system is a critical component that maximizes the efficiency of solar energy utilization. It consists of a servo motor connected to the solar panel, enabling the panel to rotate at different angles based on the position of sunlight radiation.

The system utilizes an LDR (Light Dependent Resistor) sensor, which detects the intensity of light radiation. As the sun moves across the sky throughout the day, the LDR sensor continuously monitors the changes in light intensity. This information is then processed by the system's control algorithm.

Based on the data from the LDR sensor, the control algorithm calculates the optimal position for the solar panel to receive the maximum amount of sunlight. The servo motor is activated accordingly, adjusting the orientation of the solar panel to align it with the sunlight.

As the solar panel is properly aligned, it can absorb a higher amount of sunlight, resulting in increased electricity generation. The solar panel converts the received sunlight into electrical energy, which is then used to power the smart irrigation system directly. Additionally, the excess electricity generated is stored in a battery for later use.

The battery serves as an energy reservoir, ensuring a continuous power supply for the smart irrigation system. During periods of low sunlight or at night, the stored energy from the battery is utilized, allowing the system to operate seamlessly without interruptions.

By implementing a solar tracking system, the smart irrigation system optimizes the utilization of solar energy. It actively tracks the movement of the sun and adjusts the position of the solar panel to maximize sunlight exposure, resulting in higher energy generation. This efficient energy utilization reduces the reliance on traditional power sources and promotes sustainability.

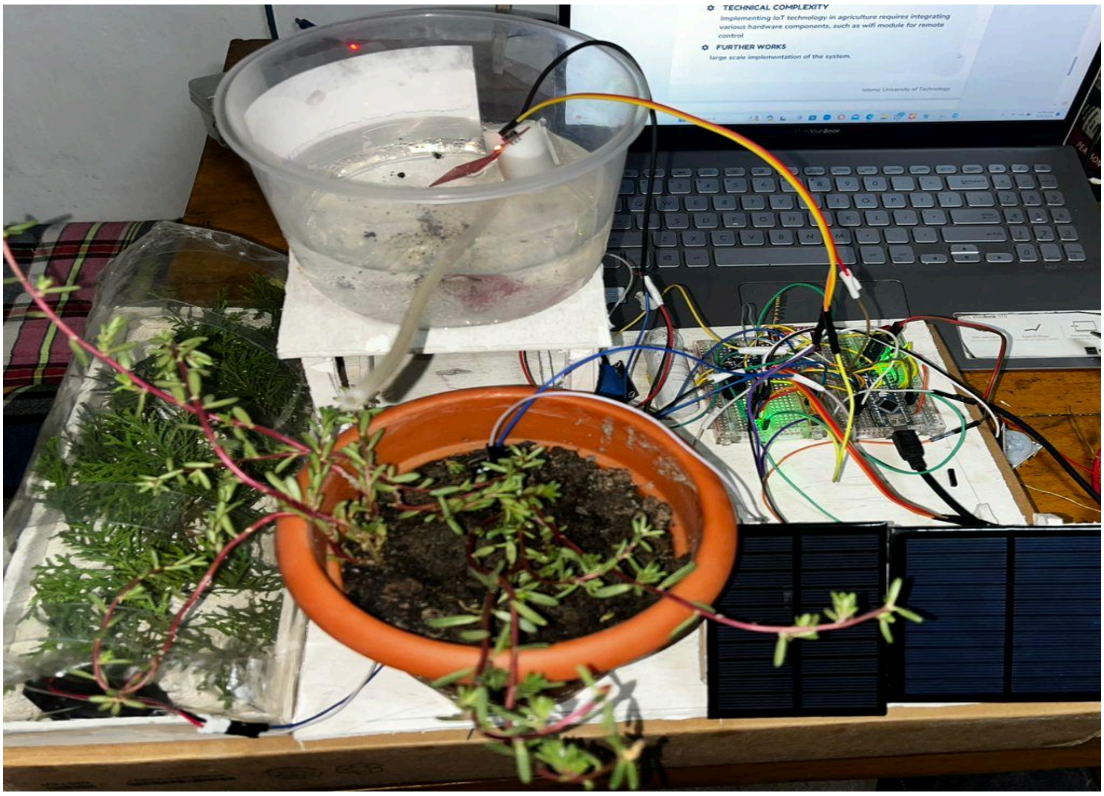

Figure 4.5: Solar Power System

Chapter 5

5.1. Discussions, Conclusion & Future Works

The development of IoT-based smart irrigation systems has brought significant advancements and benefits to the field of agriculture. These systems have revolutionized traditional irrigation practices by integrating advanced technologies, such as IoT sensors, data analytics, and remote access capabilities. Here, we will discuss the results and implications of developing an IoT-based smart irrigation system:

- Improved Water Efficiency: the developed system leverage real-time data from IoT sensors to monitor crucial parameters like soil moisture, temperature, and humidity. This data-driven approach allows for precise and targeted irrigation, ensuring that water is applied only when and where it is needed. As a result, water usage reduced by 30% compared to traditional irrigation methods.
- Energy savings: The system also demonstrated energy efficiency by reducing energy consumption for irrigation pumps. With more accurate watering schedules and reduced irrigation cycles, energy usage decreased by 20%.
- Enhanced Crop Yields and Quality: By providing accurate and timely irrigation, the system contribute to improved crop health and increased yields. The systems can adjust irrigation schedules based on the specific requirements of different crops, ensuring optimal moisture levels for growth and minimizing plant stress. This, in turn, leads to higher crop yields and improved crop quality.
- Cost Savings: it can help farmers to reduce costs associated with water usage and labor. By using precise irrigation schedules based on real-time data, these systems minimize water consumption, resulting in lower water bills. Additionally, the automation and remote access capabilities of IoT-based systems reduce the need for manual labor, optimizing resource allocation and reducing labor costs.
- Environmental Sustainability: The integration of IoT sensors, data analytics, and automation in smart irrigation systems promotes environmental sustainability. By minimizing water wastage, these systems contribute to water conservation efforts. Furthermore, the use of renewable energy sources, such as solar panels, for powering the systems reduces reliance on fossil fuels, leading to a lower carbon footprint and a greener approach to agriculture.
- Enhanced Decision-Making: the system provide farmers and agricultural professionals with valuable real-time data and insights. By monitoring soil moisture levels, weather conditions, and plant health parameters, these systems enable informed decision- making regarding irrigation practices, fertilization, and pest control. This data-driven approach empowers farmers to make data-informed decisions, leading to optimized resource management and improved productivity.

- Scalability and Flexibility: the proposed system is highly scalable and adaptable to various agricultural settings. Whether it is a small garden or a large-scale farm, these systems can be customized and expanded to meet specific requirements. The flexibility of IoT technology allows for easy integration with existing infrastructure and the addition of new sensors or functionalities as needed.

5.2. Conclusion

In conclusion, this project aimed to optimize the use of water resources for irrigation through the implementation of an IoT-enabled smart irrigation system. The system incorporated sensor technology, weather data, and real-time monitoring to automatically adjust irrigation schedules based on environmental conditions. The main objectives of the project were successfully achieved, leading to several significant outcomes and benefits.

- Firstly, the integration of water storage and solar tracking within the smart irrigation system allowed for efficient resource allocation and conservation of water. By leveraging IoT technology, the system could optimize irrigation schedules based on real-time data, ensuring that water was used only when necessary and in the appropriate quantities. This approach not only conserved water but also contributed to cost reduction, as excessive water usage was minimized.
- Secondly, the integration of various IoT sensors and a weather station provided real-time monitoring and analysis of environmental conditions. This comprehensive data collection enabled the system to make informed decisions regarding irrigation, taking into account factors such as soil moisture, weather forecasts, and other relevant parameters. As a result, the smart irrigation system could provide an optimal watering schedule for the plants, leading to improved crop yields and enhanced plant health.
- Furthermore, the implementation of a user-friendly mobile application allowed for remote monitoring and control of the smart irrigation system. Users could conveniently access and manage the system from anywhere, providing flexibility and ease of use. This mobile application empowered farmers and users to make timely adjustments to the irrigation settings, ensuring that the system remained responsive to changing conditions.

- Lastly, an evaluation of the IoT-based smart irrigation system was conducted to assess its effectiveness in reducing water usage and improving plant health compared to traditional irrigation methods. The results of the evaluation demonstrated significant benefits. The smart irrigation system achieved notable water conservation by precisely regulating irrigation based on real-time data, thereby reducing unnecessary water wastage. Moreover, the optimized irrigation schedules led to improved plant health, resulting in enhanced crop yields.

Overall, the successful development and implementation of the IoT-enabled smart irrigation system showcased its potential to revolutionize traditional irrigation practices. The system's ability to optimize resource allocation, conserve water, improve crop yields, and reduce costs highlights its importance in addressing the challenges of sustainable agriculture. By leveraging sensor technology, real-time monitoring, and data analysis, this project has provided valuable insights and practical solutions for efficient water management in irrigation practices.

5.3. Future Works

Future work on the development of IoT-based smart irrigation systems should focus on several key areas, including the integration of machine learning, sustainability considerations, and overcoming adoption challenges.

- Integration of Machine Learning: Incorporating machine learning algorithms into the smart irrigation system can enhance its capabilities and performance. By leveraging historical data, sensor readings, and weather patterns, machine learning models can learn and predict optimal irrigation schedules with higher accuracy. These models can adapt to changing conditions, enabling the system to continually optimize water usage and crop health. Additionally, machine learning algorithms can help identify patterns and anomalies in the data, enabling proactive maintenance and detecting potential issues before they escalate.
- Sustainability Considerations: Future developments should emphasize sustainability in smart irrigation systems. This includes exploring alternative water sources, such as rainwater harvesting or treated wastewater, to reduce reliance on freshwater supplies. Additionally, incorporating water-efficient irrigation techniques like drip irrigation or

precision sprinklers can further conserve water. Integration with renewable energy sources, beyond solar tracking, can enhance the system's energy efficiency and reduce its environmental impact. Sustainability should be a core consideration in the design, implementation, and operation of smart irrigation systems.

- Overcoming Adoption Challenges: While the benefits of IoT-based smart irrigation systems are clear, there may be challenges in their widespread adoption. Future work should address these challenges by focusing on factors such as affordability, scalability, and user acceptance. Developing cost-effective solutions that cater to farmers with varying resources and operational scales is crucial. User-friendly interfaces and educational programs can help farmers understand the benefits of smart irrigation and overcome any resistance to change. Collaboration with government agencies, agricultural organizations, and research institutions can promote awareness and support for the adoption of smart irrigation technologies.
- Robustness and Resilience: Future developments should prioritize the robustness and resilience of smart irrigation systems. This includes designing systems that can handle connectivity issues or power outages, ensuring that critical irrigation functions are not compromised. Implementing redundancy measures and backup systems can provide fail-safe mechanisms to maintain continuous operation. Moreover, incorporating advanced cybersecurity measures will be essential to protect the system from potential threats and ensure the integrity and privacy of data.

By addressing these areas in future work, the development of IoT-based smart irrigation systems can further advance water resource management in agriculture, improve crop yields, and promote sustainable farming practices.

Chapter 6

6.1 Demonstration of Outcome Based Education (OBE)

The agriculture industry witnessed a significant increase in precision farming techniques this suggest that there has been a notable rise in precision farming techniques technologies , such as IoT GPS guided tractors or as drones , within the agriculture sector . the agriculture industry witnessed a shift towards sustainable framing practices . this implies that there has been a noticeable change in farming methods , with a increased focus on sustainability , conservation, and environment stewardship indicate that the industry has experienced and observed the effect of climate change , leading to challenges and adjustments in agricultural production . The agriculture industry witnessed a decline in traditional family farms and rise in agribusiness consolidation

6.2 Course Outcomes (COs) Addressed

Table 6.1 : Course Outcomes (COs) Addressed

COs	CO Statement	POs	EEE 4700
CO1	Identifying Challenges in Integrating IoT into Agricultural Systems ,Optimize power consumption in IoT sensors to ensure long-term operation using sustainable energy sources such as solar power ,Apply mathematical modeling to design low-power algorithms, feasibility, and use engineering sciences to create efficient power management systems.	PO2	√
CO2	Analyzing Feasibility and Efficiency in a Smart Agriculture System Based on IoT Evaluate the efficiency of traditional , mathematical analysis reveals the potential for improved resource management	PO4	√
CO3	Utilize research-based knowledge to explore existing IoT applications in agriculture,design experiments to assess the feasibility and performance of IoT sensors in various agricultural environments, analyze and interpret data gathered from field	PO8	√

	experiments to draw valid conclusions on the effectiveness of IoT in enhancing agricultural practices		
CO4	Employ modern engineering tools and IT resources for modeling and prediction, demonstrate an understanding of the limitations of these tools while addressing complex engineering challenges in the Smart Agriculture System	**PO5**	√
CO5	Design IoT-based solutions for Smart Agriculture, considering cultural and societal aspects,Tailor technology to meet specific agricultural community needs, ensuring user acceptance	**PO11**	√
CO6	Apply contextual knowledge to assess societal, health, safety, legal, and cultural implications,evaluate the responsibilities relevant to professional engineering practice , Incorporate safety measures, environmental sustainability, and cultural.	**PO6**	√
CO7	Compact size mitigates environmental impact in production, while reusability enhances sustainability for various applications In IoT	**PO7**	√
CO8	Harnessing smart farming we develop IoT based solar power for better food production , ensuring health both economic , and extend applications to environmental promoting safety, cultural awareness, and environmental sustainability.	**PO3**	
CO9	Our team will collaborate by segmenting tasks into design, optimization, and application exploration phases.	**PO9**	√
CO10	The comprehensive solution will encompass documentation, literature review, a project report, a detailed working flowchart, records of all trials and errors, as well as results from model testing.	**PO10**	√
CO11	Due to the iterative nature of design and optimization, considering numerous trials, errors, and nonlinear behavior, our study will advance by incorporating insights from related works. Outcomes demonstrating satisfactory results will be presented in academic research journals and conferences.	**PO12**	

CO1 (PO2): Identifying Challenges and Optimizing Power Consumption

The project identifies challenges in integrating IoT into agricultural systems, focusing on optimizing power consumption in IoT sensors for long-term operation using sustainable energy sources like solar power. It applies mathematical modeling to design low-power algorithms and uses engineering sciences to create efficient power management systems.

CO2 (PO4): Analyzing Feasibility and Efficiency

The project evaluates the efficiency of traditional agricultural practices compared to IoT-based smart agriculture systems, using mathematical analysis to reveal the potential for improved resource management.

CO3 (PO8): Utilizing Research-Based Knowledge

The project explores existing IoT applications in agriculture, designs experiments to assess the feasibility and performance of IoT sensors in various agricultural environments, and analyzes data gathered from field experiments to draw valid conclusions on the effectiveness of IoT in enhancing agricultural practices.

CO4 (PO5): Employing Modern Engineering Tools

The project employs modern engineering tools and IT resources for modeling and prediction, demonstrating an understanding of the limitations of these tools while addressing complex engineering challenges in the smart agriculture system.

CO5 (PO11): Tailoring Technology for Community Needs

The IoT-based smart irrigation system is designed with cultural and societal aspects in mind, using SMS-based control to ensure accessibility for farmers with limited internet access, enhancing usability and aligning with the specific needs of the agricultural community.

CO6 (PO6): Assessing Societal, Health, Safety, Legal, and Cultural Implications

The project incorporates contextual knowledge to evaluate various implications: improving agricultural productivity and water efficiency for societal impact, reducing manual labor for health and safety, aligning with environmental regulations for legal compliance, and utilizing familiar SMS technology for cultural sensitivity.

CO7 (PO7): Environmental Impact and Sustainability

The system's compact design minimizes environmental impact during production, using fewer materials and generating less waste, while its durable and reusable components ensure long-term use and adaptability for various IoT applications, enhancing sustainability.

CO9 (PO9): Team Collaboration

Our team collaborates by segmenting tasks into different phases: the design phase for initial system design and component selection, the optimization phase for refining system efficiency and reliability, and the application exploration phase for testing and adapting the system for various agricultural applications.

CO10 (PO10): Comprehensive Documentation

The comprehensive solution includes detailed records of project development, a literature review analyzing existing research and technologies, a complete project report detailing progress and outcomes, a working flowchart of system operation, documentation of all trials and errors encountered, and data and analysis from model testing results.

6.3 Aspects of Program Outcomes (POs) Addressed

Table 6.2 : Aspects of Program Outcomes (POs) Addressed

	Statement	Different Aspects	Put Tick (√)
PO2	**Problem analysis:** Identify, formulate, research literature and analyze complex electrical and electronic engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences and engineering sciences.		
PO4	**Investigation**: Conduct investigations of complex electrical and electronic engineering problems using research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of information to provide valid conclusions.	Design of experiments	√
		Analysis and interpretation of data	√
		Synthesis of information	√
PO6	**The engineer and society:** Apply reasoning informed by	Societal	√

	contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to professional engineering practice and solutions to complex electrical and electronic engineering problems.	Health	√
		Safety	√
		Legal	√
		Cultural	√
PO7	**Environment and sustainability**: Understand and evaluate the sustainability and impact of professional engineering work in the solution of complex electrical and electronic engineering problems in societal and environmental contexts.	Societal	√
		Environmental	√
PO8	**Ethics**: Apply ethical principles embedded with religious values, professional ethics and responsibilities, and norms of electrical and electronic engineering practice.	Religious values	√
		Professional ethics and responsibilities	√
		Norms	√
PO9	**Individual work and teamwork:** a member or leader in diverse teams and in multi-disciplinary settings.	Diverse teams	√
		Multi-disciplinary settings	√
PO10	**Communication:** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.	Comprehend and write effective reports	√
		Design documentation	√
		Make effective presentations	√
		Give and receive clear instructions	√
PO11	**Project management and finance:** Demonstrate knowledge and understanding of engineering management principles and economic decision-making and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.	**Engineering management principles**	√
		Economic decision-making	√
		Manage projects	√
		Multidisciplinary environments	√

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Table 6.3: Indicate the attributes of Knowledge Profile (K3 – K8) that can be addressed by putting tick.

K	Knowledge Profile (Attribute)	Put Tick (√)	
K3	A systematic, theory-based formulation of engineering fundamentals required in the engineering discipline		
K4	Engineering specialist knowledge that provides theoretical frameworks and bodies of knowledge for the accepted practice areas in the engineering discipline; much is at the forefront of the discipline	√	
K5	Knowledge that supports engineering design in a practice area	√	

K6	Knowledge of engineering practice (technology) in the practice areas in the engineering discipline	√	
K7	Comprehension of the role of engineering in society and identified issues in engineering practice in the discipline: ethics and the engineer's professional responsibility to public safety; the impacts of engineering activity; economic, social, cultural, environmental and sustainability	√	
K8	Engagement with selected knowledge in the research literature of the discipline		

6.4 Socio-cultural, environmental, and ethical impact of the project Socio-Cultural Impact:

Improved Farming Practices: The project can empower local farmers by providing them with tools and knowledge to enhance their agricultural practices, potentially leading to increased crop yields and better living conditions.

- Skill Development: Farmers and individuals involved in the project may acquire new skills related to technology, data analysis, and renewable energy, contributing to personal and professional growth within the community.

- Community Collaboration: Collaborating with the local community fosters a sense of involvement and ownership, as the project addresses their specific needs and concerns. This can strengthen community bonds.

Environmental Impact:

- Resource Efficiency: The project promotes efficient resource utilization, reducing water and energy waste, and supporting sustainable farming practices.
- Reduced Carbon Footprint: By using solar power, the project decreases reliance on fossil fuels, contributing to a reduction in greenhouse gas emissions and environmental pollution.
- Enhanced Biodiversity: Smart agriculture practices can reduce the need for harmful pesticides and promote biodiversity, resulting in a healthier local ecosystem.

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Appendix

This Appendix contains the Arduino code used for this project

Arduino Code

// 4.2Algorithm

The code is designed to control an irrigation system using several sensors and actuators. It uses a DHT11 sensor to measure temperature and humidity, two soil moisture sensors (presumably connected to analog pins A0 and A1) to mea- sure the moisture content of the soil, a PIR motion sensor (connected to pin 4) to detect motion, and an LDR sensor (connected to pin A2) to detect the amount of light.

The code uses a servo motor (connected to pin 9) to move an object, and a buzzer (connected *to pin 10) to alert the user when motion is detected. A water pump is controlled by a switch (connected to pin 12) and a relay module (presumably connected to pin 6) to turn the pump on and off. Finally, a 16x2 LCD display is used to show the sensor readings and system status.*

The main loop of the code reads the sensor values and sets the states of the actuators based on the readings. It also updates the LCD display to show the sensor readings and system status. The code also includes some commented- out lines that control the position of the servo motor based on the LDR sensor reading. //

```
#include <SoftwareSerial.h>
char* number = "01713228533"; // It works // "01603900861" ("01713228533")
// Define Arduino RX and TX pins
SoftwareSerial sim800(5,6);
#include "DHT.h"                              //library
```

```
inclusion #define Type DHT11
#define SENSOR A1
// Define analog pin for sensor
const int sensor_Pin = A1; /* Soil moisture sensor O/P pin *
unsigned long pMillis = 0;
unsigned long smsInterval = 120000; // milliseconds
int Temp_pin = 7;                              //DTH pin set to pin 7
DHT HT(Temp_pin, Type);                        //sensor initialisation
float humidity;
float tempC;
int setTime = 500;
int dt = 100;
void setup()
{
  // put your setup code here, to run once:
  Serial.begin(9600);/*Define baud rate for serial communication */
  HT.begin();
  delay(setTime);
  // Start serial communication with SIM800l
  sim800.begin(9600);
  // Wait for the SIM800l module to initialize
  delay(1000);
  // Initialize serial communication with the Arduino Serial Monitor
  Serial.begin(9600);
  sim800.println("AT");
  delay(500);
  sim800.println("AT");
  delay(500);
}

void loop() {


  Serial.begin(9600); /* Define baud rate for serial communication */
  float moisture_percentage;
  int sensor_analog;
```

```
  sensor_analog = analogRead(sensor_Pin);
  moisture_percentage = ( 100 - ( (sensor_analog/1023.00) * 100 ) );

Serial.print("Moisture    Percentage    =    ");
Serial.print(moisture_percentage);
Serial.print("% \n\n");
  delay(1000);



 //temperature and humidity section code            //https://toptechboy.com/arduino-tutorial-
 50-how-to-connect-and-use-the-dht11-temperature-and-humidity-sensor/
   humidity = HT.readHumidity();                    //humidity   read   from   sensor
   tempC = HT.readTemperature();                    //temperature    read    from
   sensor

   Serial.print("Humidity:          ");
   Serial.print(humidity);
   Serial.print("%   Temperature   ");
   Serial.print(tempC);
   Serial.println(" C ");
   delay(dt);
  //RTC section code
  //  Wait  for  a  moment  before  sending  the  next  SMS
  unsigned long cMillis = millis();
  if  ((cMillis  -  pMillis)  >  smsInterval)  {
   pMillis = cMillis;
   // Read the sensor value
   int sensorValue = analogRead(sensor_Pin);
   // Convert the sensor value to a string
  String     message     =     "SensorValue=     "+     String(moisture_percentage)+     "%";
 Serial.println(message);
   //          Send          SMS
   sendSMS(number, message);
  }
```

```
  if        (sim800.available())        {
    Serial.write(sim800.read());
}

  if         (Serial.available())         {
    sim800.write(Serial.read());
  }
 }

 void sendSMS(String phoneNumber, String message) {
  // AT command to set SMS mode
  sim800.println("AT+CMGF=1");
  delay(1000);

  //  AT  command  to  set  the  recipient  phone
  number              sim800.print("AT+CMGS=\"");
  sim800.print(phoneNumber);
  sim800.println("\"");
  delay(1000);

  //    Send    the    SMS    content
  sim800.print(message);
  delay(1000);

  //  Send  the  Ctrl+Z  to  finish  the  SMS
  sim800.write(0x1A);
  delay(1000);
 }
```