Design and Implementation of an IOT-Based Smart Green House Monitoring System Using IOT

Badipati Chinna Babu [1], D. Anjaneyulu [2], P. Pragathi [3], P. Bhuvaneswari [4], V. Narasimha Rao [5], M.Vamsi Naik[6]

[1] *Assistant Professor, A.M Reddy memorial college of engineering and technology, Department of Agricultural Engineering*

[2,3,4,5,6] *Student, A.M Reddy memorial college of engineering and technology, Department of Agricultural engineering*

***Abstract*-The Greenhouse Monitoring System (GMS) using Internet of Things (IoT) technology provides an innovative solution for efficient agricultural management. This system leverages IoT devices, sensors, and real-time data analytics to monitor and control environmental parameters such as temperature, humidity, soil moisture, and light intensity within a greenhouse. By integrating IoT, the system allows farmers to remotely access data through a mobile application or web interface, enabling them to make informed decisions about irrigation, ventilation, and overall crop management. The use of IoT not only ensures optimal conditions for plant growth but also promotes resource efficiency by reducing water wastage and energy consumption. Moreover, the system's automation features can activate irrigation systems, adjust lighting, and control ventilation without manual intervention, leading to increased productivity, reduced operational costs, and a more sustainable approach to agriculture. Overall, the Greenhouse Monitoring System using IoT represents a transformative advancement in precision farming, driving innovation and sustainability in modern agriculture.**

***Key Words:* Greenhouse Monitoring System, Internet of Things (IoT), Smart Agriculture, Automation, Precision Farming.**

I.INTRODUCTION

In recent years, the agriculture industry has been evolving with the advancement of technology. One such innovation is the integration of Internet of Things (IoT) in greenhouse management. The Greenhouse Monitoring System using IoT is a modern solution aimed at enhancing the efficiency and productivity of farming operations. This system utilizes IoT devices, sensors, and real-time data analytics to monitor and control crucial environmental factors within a greenhouse, such as temperature, humidity, soil moisture, light intensity, and CO2 levels.

The traditional methods of greenhouse management are labour-intensive, and often prone to inefficiencies such as resource wastage and inconsistent crop yields. IoT-based systems address these challenges by automating various processes and enabling remote monitoring. This allows farmers to continuously observe the greenhouse conditions from anywhere, using smartphones, computers, or other digital interfaces.

By connecting sensors to the cloud, data is collected and analysed in real time, providing insights into the optimal conditions for plant growth. Automated systems, such as irrigation, ventilation, and lighting, can be adjusted based on these insights, ensuring that plants thrive in a controlled environment. Additionally, IoT technology helps in conserving water, energy, and other resources, leading to more sustainable farming practices.

The Greenhouse Monitoring System using IoT is not just a technological upgrade; it is a transformative solution for modern agriculture that contributes to increased crop yield, reduced operational costs, and better resource management, paving the way for a smarter and more sustainable future in farming.

OBJECTIVES OF THE CURRENT STUDY

- To design and development of an IOT based prototype Greenhouse monitoring system.
- To Continuously monitoring of environmental parameters like temperature, humidity, soil moisture and light levels to ensure optimal growing conditions.
- To evaluate performance of IOT based prototype greenhouse monitoring system.

II.REVIEWS AND LITERATURE

"Advancements in Greenhouse Climate Control Systems Using IoT" (2022) Kumar et al. review the technological advancements in greenhouse climate control systems that use IoT for real-time data collection and automated control, leading to improved energy efficiency and higher productivity.

"IoT-Enabled Smart Greenhouse for Precision Agriculture" (2021) Jain and Prakash discuss how IoT technologies in greenhouses support precision farming by providing real-time environmental monitoring and automation, leading to better crop management and yield.

"IoT-Based Environmental Monitoring and Control for Sustainable Greenhouse Management" (2021) Singh and Gupta discuss how IoT-based monitoring systems can facilitate sustainable greenhouse management. They emphasize the use of IoT sensors to manage environmental conditions, improve energy efficiency, and reduce operational costs.

"IoT-Enabled Smart Agriculture: A Review of Applications in Greenhouse Monitoring" (2021) Singh et al. review the applications of IoT in greenhouse monitoring, including temperature, humidity, and soil moisture sensors. They explore how these sensors improve resource conservation, increase productivity, and reduce operational costs.

"Smart Greenhouse Monitoring System Using IoT and Big Data Analytics" (2021) Wang et al. explore how big data analytics combined with IoT technologies can improve greenhouse monitoring systems. The study demonstrates how data collected from various sensors can be analysed to provide insights into optimizing greenhouse operations and improving crop yield.

"A Survey of IoT Applications in Agriculture" (2020) Gómez et al. provide a broad survey of IoT applications in agriculture, emphasizing the benefits of IoT in greenhouse management, such as precise environmental control, automation, and data-driven decision-making.

"Real-Time Greenhouse Environmental Monitoring Using IoT" (2020) Joshi et al. investigate a real-time greenhouse monitoring system using IoT. The study explores the integration of sensors and cloud technology to provide live data to greenhouse managers, improving decision-making and system automation.

"Optimization of Greenhouse Operations Using IoT-Enabled Sensors" (2020) Lee et al. focus on how IoT-enabled sensors can optimize greenhouse operations. They examine automated systems that adjust temperature, humidity, and CO2 levels to optimize plant growth and improve resource management.

"Energy-Efficient Greenhouse Monitoring Using IoT" (2020) Li et al. explore energy-efficient greenhouse monitoring systems using IoT. The paper discusses how IoT can help optimize lighting, ventilation, and heating systems to reduce energy consumption while maintaining optimal growing conditions.

"A Comprehensive Review of IoT Applications in Greenhouses" (2020) Malarvizhi et al. conduct a comprehensive review of IoT applications in greenhouses, highlighting the integration of sensors, actuators, and cloud computing platforms to enable remote control and optimize greenhouse conditions.

"Design and Implementation of an IoT-Based Smart Greenhouse" (2020) Reddy et al. focus on the design and implementation of an IoT system for smart greenhouse management. The study demonstrates how IoT sensors monitor environmental factors, automate systems, and conserve resources, resulting in better crop growth.

"Sustainability in Greenhouse Agriculture through IoT" (2020) Tufail et al. examine how IoT systems enable sustainability in greenhouse agriculture by monitoring and automating resource usage. The study emphasizes the role of IoT in water and energy conservation.

"Wireless IoT Solutions for Greenhouse Automation and Remote Monitoring" (2020) Zafar et al. investigate wireless IoT solutions for greenhouse automation and remote monitoring. The research discusses how wireless sensor networks can be used to gather data from multiple environmental parameters, making it easier for farmers to monitor and control greenhouse conditions remotely.

"Smart Greenhouse Management Using IoT" (2019) Al-Fuqaha et al. focus on the integration of IoT in greenhouse management. They review how sensor networks, cloud computing, and automated systems contribute to sustainable farming practices, reducing water consumption, and enhancing crop quality.

"Cloud-Based IoT System for Greenhouse Monitoring and Control" (2019) Patel et al. propose a cloud-based IoT system for greenhouse monitoring and control. The system integrates sensors to monitor environmental parameters and uses cloud computing for data processing and remote access.

"Greenhouse Automation System Using IoT and Machine Learning" (2019) Sharma and Verma present an IoT-based greenhouse automation system that integrates machine learning algorithms to predict environmental changes and optimize climate control systems in real-time, enhancing crop growth and reducing energy use.

"Smart Irrigation System for Greenhouses Using IoT" (2019) Sharma et al. explore how IoT-based smart irrigation systems help optimize water usage in greenhouses. The paper highlights how moisture sensors connected to IoT systems reduce water wastage and maintain the optimal soil condition for crops.

"Internet of Things for Precision Agriculture in Greenhouses" (2018) Rajalakshmi and Ramesh discuss how IoT systems are being utilized for precision agriculture in greenhouses. They focus on the role of IoT in optimizing irrigation, lighting, and climate control for better crop yield and sustainability.

"IoT-Based Greenhouse Automation Systems" (2018) Zhou et al. explore IoT-based greenhouse automation systems for monitoring and controlling environmental factors like temperature, humidity, and soil moisture. The study demonstrates that IoT systems reduce human intervention, enhance resource efficiency, and increase crop yields.

"Wireless Sensor Networks for Greenhouse Environmental Monitoring" (2017) Akyildiz et al. explore the use of wireless sensor networks (WSNs) for environmental monitoring in greenhouses. They highlight the advantages of WSNs in reducing wiring complexity and providing real-time data for decision-making.

III.MATERIALS AND METHODS

ARDUINO UNO BOARD:

The Arduino Uno is one of the most popular microcontroller development boards used for creating interactive electronics projects. It is an open-source hardware platform that makes it easy for beginners and experts alike to build digital devices and interactive systems. The Uno board is based on the ATmega328P microcontroller and can be programmed using the Arduino IDE (Integrated Development Environment).

1.Microcontroller: The board uses the ATmega328P microcontroller, which is an 8-bit microcontroller with a built-in EEPROM, Flash memory, and SRAM.

2.Digital I/O Pins: 14 digital I/O pins, which can be used as input or output (6 of which can be used for PWM output).

PWM (Pulse Width Modulation) is used for controlling devices like motors, LEDs, and other analogy components.

3.Analog Input Pins: 6 analogy input pins for reading analogy signals (e.g., from sensors like temperature sensors, light sensors, etc.).

4.Clock Speed: The clock speed of the Arduino Uno is 16 MHz, which determines how fast the board can process data and execute code.

5.Power Supply: The board can be powered via USB or an external DC power jack (7V to 12V).

It has a built-in voltage regulator that provides 5V to power the board and peripherals.

6.Memory: Flash Memory: 32 KB, where the program code is stored.

SRAM (Static RAM): 2 KB for runtime data.

EEPROM (Electrically Erasable Programmable Read-Only Memory): 1 KB for long-term storage of data.

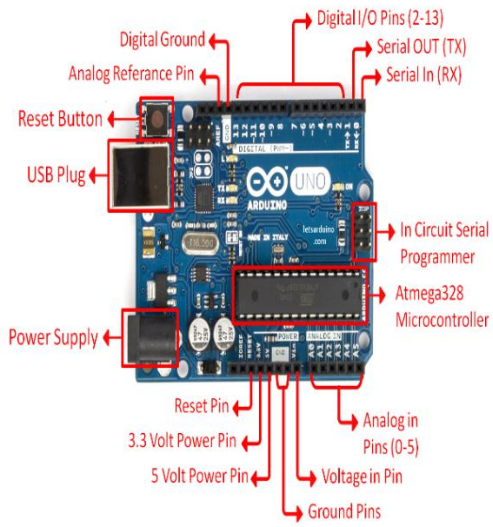

Fig :2 Arduino Board

7.USB Connection: The Arduino Uno board has a USB-B port that allows you to connect the board to a computer for uploading code and communication with the Arduino IDE.

8.Reset Button: The board has a reset button that can restart the program running on the microcontroller.

9.Communication Ports: The Serial communication is done via the USB or through the TX/RX pins (digital pins 0 and 1).

It can also communicate with other devices using protocols like I2C, SPI, and UART.

10.External Connectivity: ICSP (In-Circuit Serial Programming) header for direct programming of the microcontroller.

The board supports communication protocols like I2C (Inter-Integrated Circuit) and SPI (Serial Peripheral Interface) for communication with other devices like sensors and displays.

11.Onboard LED: The Arduino Uno has an onboard LED connected to pin 13, which can be used for debugging or simple visual feedback.

RELAY:

A relay is an electrically operated switch that allows one circuit to control another, typically with a low voltage or current controlling a higher voltage or current. It is widely used in automation, robotics,

Fig :3 Relay

control systems, and many other applications where it's necessary to control a high-power device with a low-power signal.

LCD:

LCD stands for Liquid Crystal Display. It is a type of flat-panel display technology that uses liquid crystals to produce images. These liquid crystals do not emit light by themselves but instead use a backlight to create visible images. The liquid crystals are sandwiched between two layers of glass or plastic panels, and when an electric current is applied, they align in a way that allows light to pass through in varying amounts, creating the images you see on the screen.

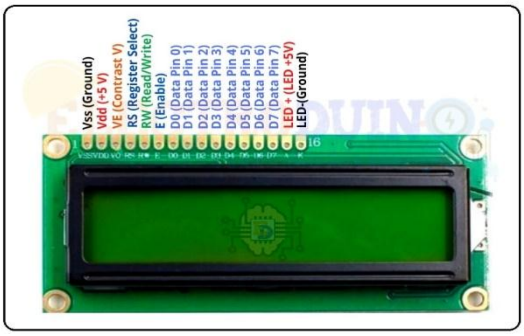

Fig: 4 16*2 Lcd

Thin and lightweight: They are much thinner and lighter than older CRT (Cathode Ray Tube) displays.

Energy-efficient: LCDs consume less power compared to older display technologies.

Sharp images and good colour reproduction: They offer clear, high-quality visuals, although they typically have lower contrast ratios compared to other display technologies like OLED.

Backlighting: LCDs need a backlight, typically made of LED (Light Emitting Diode) lights, to illuminate the display.

L298N MOTO DRIVER:

The L298N motor driver controls DC and stepper motors with bi-directional control. It supports 4.5V to 35V motor power and 5V logic. With PWM, it enables speed control and can handle up to 2A per motor. Pins IN1, IN2, IN3, IN4 control motor direction, while ENA, ENB handle speed. Commonly used in robotics for motor control with an Arduino or similar microcontrollers.

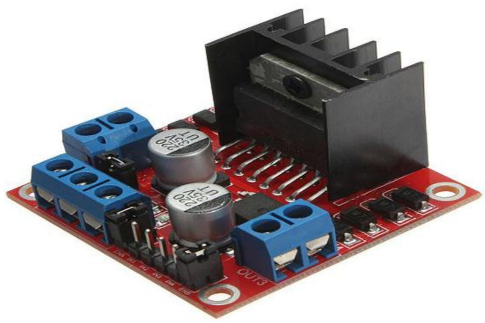

Fig :5 L298N Moto Driver

DHT-11 SENSOR:

The DHT-11 is a digital sensor that measures temperature (0°C to 50°C) and humidity (20% to

90% RH). It provides data via a single-wire digital output. The sensor operates with a 3.3V to 5V power supply and has a simple interface for microcontrollers like Arduino. It has a ±2°C temperature accuracy and ±5% humidity accuracy. The sensor is commonly used in weather stations and home automation projects.

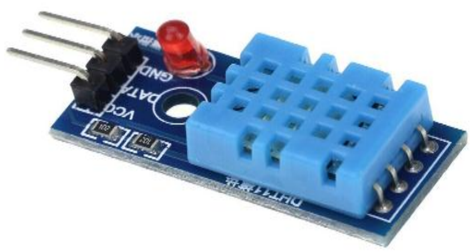

Fig: 6 DHT-11 SENSOR

JUMPER WIRES:

Jumper wires are used to connect components on a breadboard or to a microcontroller. They come in male-to-male, female-to-female, and male-to-female varieties. They are essential for prototyping and quick circuit connections. Jumper wires are flexible and easy to use, making them ideal for DIY electronics.

Fig :7 Jumper Wires

BLUETOOTH MODULE(HC-06):

The HC-06 Bluetooth module allows wireless communication between microcontrollers and Bluetooth-enabled devices. It uses UART (TX, RX) for data transmission and operates at 3.3V to 5V. The module works in slave mode, meaning it connects to master devices like smartphones or PCs. It has a typical range of 10 meters and is widely used in projects like wireless control systems. The module is easy to integrate with platforms like Arduino.

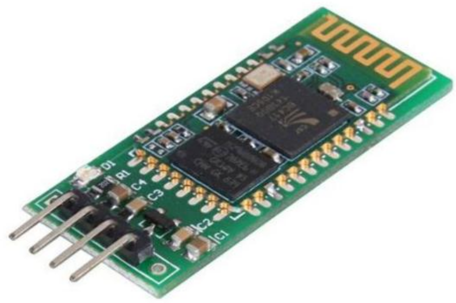

Fig :8 Bluetooth Module (Hc-06)

BATTERY:

A battery stores chemical energy and converts it into electrical energy. It consists of one or more electrochemical cells. Batteries come in different types, such as alkaline, Li-ion, Li-Po, and NiMH. They vary in voltage (e.g., 1.5V for AA, 3.7V for Li-ion) and capacity (measured in mAh or Ah). Battery usage in IoT-based greenhouse monitoring systems is optimized for energy efficiency.

Fig: 9 Battery

These systems typically rely on rechargeable batteries powered by renewable sources like solar panels. Low-power sensors and microcontrollers are used to minimize energy consumption.

MOTOR PUMP:

Motor pumps play a vital role in greenhouse monitoring systems, especially in automating irrigation. These pumps are controlled by IoT-enabled systems that monitor soil moisture levels using sensors. When the moisture level drops below a set threshold, the system activates the motor pump to supply water to the plants. This ensures efficient water usage and reduces manual intervention, promoting sustainable agriculture.

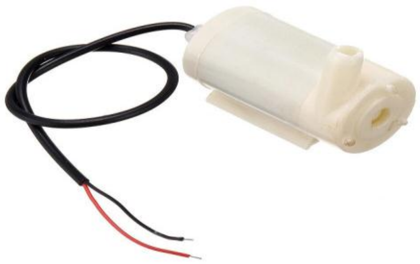

Fig: 10 Motor Pump

SOIL MOISTURE SENSOR:

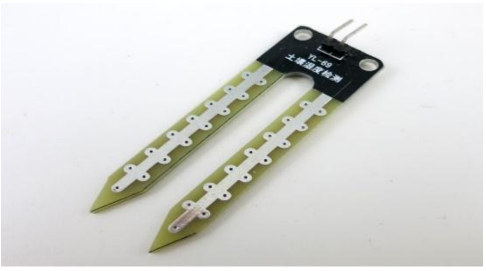

Fig:11 Soil Moisture Sensor

Soil moisture is a key factor in plant health and effective irrigation in greenhouses. IoT-based systems measure soil moisture levels using sensors to ensure plants receive the right amount of water. These sensors detect the volumetric water content in the soil and transmit data to a microcontroller, which can activate motor pumps when moisture levels drop below a set threshold. Proper soil moisture monitoring promotes sustainable water usage and optimizes plant growth.

COOLING FAN:

Fig:12 Cooling Fan

Cooling fans are essential in maintaining optimal temperatures within a greenhouse. IoT-based systems can monitor temperature and humidity levels using sensors and automatically activate cooling fans when needed. This helps to regulate the environment, preventing heat stress on plants and ensuring healthy growth. The integration of smart controls ensures energy-efficient operation, only running the fans when conditions demand cooling.

POWER ADAPTOR:

A power adaptor in an IoT-based greenhouse monitoring system is essential for converting AC power from the mains into DC power suitable for various IoT components. It ensures a stable power supply, preventing fluctuations that could interfere with sensitive devices like sensors and microcontrollers. Choosing an energy-efficient adaptor supports sustainable practices, and the selection is based on the voltage and current requirements of the setup. This enables reliable operation of pumps, cooling systems, soil moisture sensors, and other monitoring devices, ensuring the system runs seamlessly.

Fig:13 Power Adaptor

USB A TO B CABLE:

In an IoT-based greenhouse monitoring system, a USB A to B cable can be used to connect devices like microcontrollers (e.g., Arduino) to computers for programming or data transfer. It ensures seamless communication between the hardware and software, allowing you to upload code, retrieve sensor data, or monitor system performance. This cable is particularly useful during the setup and debugging phases of your project.

Fig:14 USB A To B Cable

METHODOLOGY

The methodology for an IoT-based Greenhouse Monitoring System involves the systematic design and implementation of hardware and software components to ensure efficient environmental control within a greenhouse. This system leverages sensors, microcontrollers, wireless communication, cloud storage, automation, and user interfaces to enable real-time monitoring and control of crucial parameters such as temperature, humidity, soil moisture, light intensity, and CO_2 concentration. By integrating IoT technology, this system provides an intelligent solution for optimizing plant growth conditions, minimizing human intervention, and improving agricultural productivity.

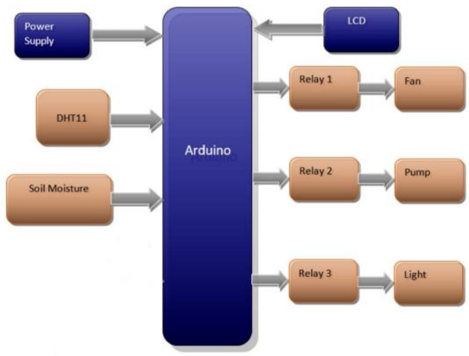

Fig : 15 block diagram of green house monitoring system.

3.16 SYSTEM DESIGN AND COMPONENT SELECTION

In the initial phase of designing a greenhouse monitoring system using IoT, it is essential to define the system requirements clearly. The primary objective is to maintain optimal environmental conditions for plant growth. This involves identifying and monitoring key parameters such as temperature, humidity, and soil moisture. These factors significantly affect the health and productivity of crops. For effective automation, ideal threshold values for each parameter must be determined based on the specific needs of the crops being grown. For instance, for most vegetables, the ideal temperature range is between 20°C to 30°C, relative humidity should be between 50% to 70%, and soil moisture should remain above 30% to avoid drying out. These threshold values guide the system’s automated responses, such as turning on the fan when the temperature rises or activating the water pump when the soil becomes too dry. Accurate definition of these parameters is crucial for the system's reliability and efficiency.

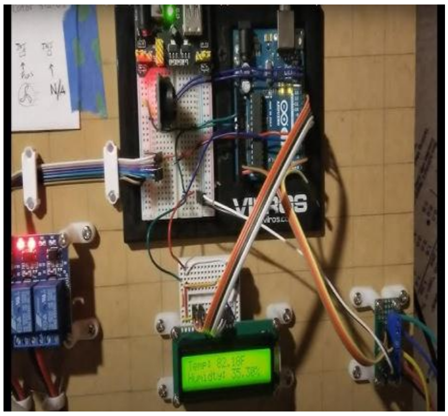

Fig:16 Hardware kit image

3.17 Sensor calibration:

Sensor calibration is a vital process in the greenhouse monitoring system using IoT, as it ensures the accuracy and reliability of environmental data collected by the sensors. Inaccurate sensor readings can lead to incorrect system responses, such as overwatering or insufficient ventilation, which may harm plant health. Calibration involves adjusting the sensor outputs to match known, accurate reference values. For instance, the DHT11 or DHT22 sensor used for measuring temperature and humidity should be compared with a reliable thermometer and hygrometer. Any discrepancies can be corrected using software offsets in the microcontroller code. Similarly, soil moisture sensors need to be calibrated based on the soil type. This is typically done by recording sensor values in completely dry soil (0% moisture) and fully saturated soil (100% moisture), and then mapping these readings to a scale in the code. Regular calibration ensures that the system responds appropriately to real-time conditions, maintaining an ideal environment for plant growth.

3.18 Data collection and processing:

Data collection and processing are core components of the greenhouse monitoring system using IoT. The system continuously gathers real-time environmental data through various sensors, such as temperature and humidity sensors (e.g., DHT11/DHT22) and soil moisture sensors. These sensors are connected to a microcontroller, such as Arduino or ESP32, which acts as the brain of the system. The microcontroller reads sensor values at regular intervals and processes the data to determine if environmental conditions fall within the predefined optimal ranges. If any parameter exceeds or falls below the threshold, the system triggers appropriate actions—such as activating a fan for cooling or turning on a water pump for irrigation. In addition, the processed data is transmitted via Wi-Fi to an IoT platform like Blynk or Thing Speak. This allows remote monitoring through a smartphone or computer, and enables users to analyze trends, receive alerts, and manually control devices when necessary. Accurate data processing ensures efficient greenhouse automation and healthy plant growth.

3.19Threshold setting and alert:

Threshold setting and alerts play a critical role in the effective operation of a greenhouse monitoring system using IoT. Thresholds are predefined limit values for key environmental parameters such as temperature, humidity, and soil moisture, based on the specific needs of the plants being cultivated. For example, a temperature threshold might be set at 30°C, a humidity limit at 80%, and a soil moisture minimum at 30%. When sensor readings exceed or fall below these set values, the microcontroller processes the data and triggers automatic responses—such as activating the fan, turning on the water pump, or sending an alert to the user. These alerts are transmitted through the IoT platform via mobile apps, SMS, or email, depending on the system configuration. This allows greenhouse operators to be notified instantly of any abnormal conditions, even when they are offsite. Proper threshold setting and timely alerts help prevent crop stress or damage, ensuring stable and healthy plant growth in a controlled environment.

SOFTWARE EXPLANATION

upload the code to Arduino board (using the Arduino IDE), here's what happens:

- The code (called a *sketch*) is compiled into machine code.
- It gets uploaded and stored in the Arduino's flash memory (non-volatile memory), so it stays even after power is turned off.
- The Arduino then runs this code in a loop (void loop ()) forever (or until reset).

So, the code is installed on the Arduino board itself, not your computer.

CODING USED:

```
#include < DHT. h >
#define DHTPIN 2          // Pin for the DHT11 sensor data
#define DHTTYPE DHT11     // Specify DHT sensor type (DHT11)
#define IN1 9             // IN1 of L298N
#define IN2 10            // IN2 of L298N
#define ENA 5             // Enable pin of L298N (can be connected to PWM pin for speed control)
DHT (DHTPIN, DHTTYPE); // Initialize DHT sensor
void setup () {
  Serial. Begin (9600);
  // Initialize pins
  Pin Mode (IN1, OUTPUT);
  Pin Mode (IN2, OUTPUT);
  pin Mode (ENA, OUTPUT);
  // Initialize DHT sensor
  DHT. begin ();
  // Set initial fan speed to 0 (off)
  Analog Write (ENA, 0);
}
void loop () {
  // Read the temperature (Celsius)
  float temp = DHT. read Temperature ();
  if (is nan (temp)) {
    Serial. Print ln ("Failed to read from DHT sensor!");
    return;
  }
  Serial. Print ("Temperature: ");
  Serial. Print (temp);
  Serial. Print ln (" °C");
  // Adjust fan speed based on temperature
  if (temp < 25) {
    // Fan off or low speed (if temperature is less than 25°C)
    Analog Write (ENA, 0);
  } else if (temp >= 25 && temp < 30) {
```

```
    // Low fan speed (25-30°C)
    Analog Write (ENA, 128); // Half-speed
  } else if (temp >= 30 && temp < 35) {
    // Medium fan speed (30-35°C)
    Analog Write (ENA, 192); // Medium speed
  } else {
    // High fan speed (above 35°C)
    analog Write (ENA, 255); // Full speed
  }
  // Control direction if needed (this can be left or right depending on your fan)
  digital Write (IN1, HIGH);
  digital Write (IN2, LOW)
  delay (2000); // Delay for a couple of seconds before the next reading
```

CODE FOR SOIL MOISTURE:

```
#include
#include
Software Serial my Serial (9,10);
Int M Sensor = A0;
int W led = 7;
int P led = 13;
Liquid Crystal lcd (12, 11, 5, 4, 3, 2);
void setup ()
{
LCD. Begin (16, 2);
My Serial. Begin (9600);
pin Mode (7, INPUT);
pin Mode (13, OUTPUT);
}
LCD. Clear ();
int Moist = analog Read (Sensor);
if (Moist> 700) // for dry soil
{
lcd. Set Cursor (11,0);
lcd. Print("DRY");
lcd. Set Cursor (11,1);
lcd. Print("SOIL");
if (digital Read (W led) ==1) //test the availability of water in storage
{
digital Write (13, HIGH);
lcd. Set Cursor (0,1);
lcd. Print ("PUMP: ON");
my Serial. Print ln ("AT+CMGF=1");
delay (1000);
my Serial. Print ln ("AT+CMGS=\" NUMBER" \r");
delay (1000);
my Serial. Print ln ("PUMP: ON");
delay (100);
my Serial. Print ln((char)26);
delay (1000);
}
else
{
digital Write (13, LOW);
lcd. Set Cursor (0,1);
lcd. Print ("PUMP: OFF");
my Serial. Print ln("AT+CMGF=1");
delay (1000);
my Serial. Print ln ("AT+CMGS= \" NUMBER" \r");
delay (1000);
my Serial. Print ln ("PUMP: OFF");
delay (100);
my Serial. Print ln((char)26);
delay (1000);
}
```

```
}
if (Moist>= 300 && Moist<=700) //for Moist Soil
{
lcd. Set Cursor (11,0);
lcd. Print(“MOIST”);
lcd. Set Cursor (11,1);
lcd. Print (“SOIL”);
digital Write (13, LOW);
lcd. Set Cursor (0,1);
lcd. Print (“PUMP: OFF”);
my Serial. Print ln (“AT+CMGF=1”);
delay (1000);
my Serial. Print ln (“AT+CMGS=\” NUMBER” \r”);
delay (1000);
my Serial. Print ln (“PUMP: OFF”);
delay (100);
my Serial. Print ln((char)26);
delay (1000);
}
if (Moist < 300) // For Soggy soil
{
lcd. Set Cursor (11,0);
lcd. Print (“SOGGY”);
lcd. Set Cursor (11,1);
lcd. Print (“SOIL”);
digital Write (13, LOW);
lcd. Set Cursor (0,1);
lcd. Print (“PUMP: OFF”);
my Serial. Print ln(“AT+CMGF=1”);
delay (1000);
my Serial. Print ln (“AT+CMGS=\” NUMBER” \r”);
delay (1000);
My Serial. Print ln (“PUMP: OFF”);
delay (100);
my Serial. Print ln((char)26);
delay (1000);
}
delay (1000);
```

3.20 Testing and validation:

Testing and validation are essential stages in the development of a greenhouse monitoring system using IoT to ensure the system functions accurately and reliably under real-world conditions. After assembling the hardware and uploading the control code, the entire system is tested in a controlled environment to observe its behaviour in response to varying temperature, humidity, and soil moisture levels. Each sensor is verified for accuracy by comparing its readings with standard measuring instruments. The automated actions, such as the activation of the water pump and cooling fan, are also tested to confirm they respond correctly to threshold breaches. Furthermore, the data transmission to the IoT platform is monitored to ensure real-time updates and alerts are functioning properly. Any discrepancies or system errors observed during testing are corrected by fine-tuning the code, recalibrating the sensors, or adjusting the threshold settings. Successful validation confirms that the system is ready for deployment and capable of maintaining optimal greenhouse conditions effectively.

Fig:17 LCD display parameters

DISCUSSION

The integration of Internet of Things (IoT) into greenhouse monitoring systems is revolutionizing the way we manage and optimize agricultural environments. With the world’s population steadily increasing, food security and sustainable agricultural practices have become critical concerns. IoT-based greenhouse monitoring systems offer an innovative solution to improve crop yields, reduce resource consumption, and enhance the efficiency of greenhouse operations.

1. Real-time Monitoring and Control:

One of the most significant advantages of an IoT-based greenhouse system is its ability to provide real-time monitoring. Sensors placed throughout the greenhouse can continuously track vital environmental parameters such as temperature, humidity, soil moisture, light levels, and CO2 concentration. This data is then sent to a cloud-based platform, allowing farmers to remotely monitor the greenhouse environment from their smartphones or computers. The real-time data provides an accurate picture of the plant's immediate needs, enabling immediate adjustments to be made. For example, if the humidity levels rise too high, the system can activate ventilation or dehumidifiers to bring the conditions back to optimal levels.

2. Automation and Precision Farming:

Automation is another key feature of IoT-based greenhouse systems. Based on the data collected from the sensors, the system can automatically adjust environmental factors. Irrigation systems can be triggered when soil moisture levels drop, while lighting systems can be adjusted based on the amount of natural sunlight available. Temperature regulation is also automated, with heating and cooling systems activated as needed. This level of automation helps ensure that the plants are always in the ideal environment for growth, minimizing human intervention and reducing labour costs.

3. Data-Driven Insights:

IoT systems generate large amounts of data that can be analysed to improve decision-making. With historical data logging, greenhouse managers can identify trends, understand plant growth patterns, and make better predictions for future crops. For instance, a farmer could identify that certain plants thrive at specific humidity levels or during particular seasons, which allows them to tailor the environment for those plants' needs more precisely. Additionally, by analysing trends over time, farmers can anticipate potential issues before they become serious, such as predicting disease outbreaks based on environmental stress indicators.

4. Energy and Resource Efficiency:

One of the most important benefits of an IoT-based greenhouse monitoring system is its contribution to resource optimization. Traditional greenhouses often suffer from inefficiencies in terms of energy consumption, water usage, and the overall environmental impact. IoT systems help mitigate these issues by optimizing energy use. For instance, automated irrigation systems ensure water is only used when needed, reducing waste. Similarly, the lighting and climate control systems can adjust based on the time of day or changing weather conditions, reducing unnecessary energy consumption. By maximizing resource efficiency, an IoT-based system reduces the overall carbon footprint of the greenhouse, promoting more sustainable farming practices.

5. Cost-Effectiveness and Return on Investment (ROI):

While the initial investment in IoT technology may be higher compared to traditional methods, the long-term cost savings can be significant. With better resource management, automated controls, and increased crop yield, the ROI for IoT-based greenhouse systems become evident. Reduced labour costs, fewer crop failures due to environmental stresses, and less waste in water and energy consumption all contribute to a more profitable greenhouse operation. Furthermore, the system's ability to optimize growth conditions can lead to faster and healthier plant development, allowing for higher productivity per square meter.

6. Challenges and Considerations:

Despite the numerous benefits, there are certain challenges to implementing an IoT-based greenhouse monitoring system. One of the primary challenges is the initial cost of installing IoT devices and the required infrastructure, including sensors, controllers, and cloud-based platforms. For small-scale farmers, the upfront investment might be prohibitive. Additionally, there may be concerns regarding data security and privacy, as the reliance on cloud-based systems means that sensitive data is being transmitted over the internet.

7. Future Prospects and Developments:

The future of IoT-based greenhouse systems looks promising. As technology continues to evolve, we can expect improvements in sensor accuracy, automation capabilities, and system integration. Artificial intelligence (AI) and machine learning may play an increasingly important role, allowing systems to learn from data and make even more precise predictions and adjustments. Additionally, the integration with other agricultural technologies, such as drones for crop monitoring and soil health analysis, could create a highly interconnected, intelligent farming ecosystem.

RESULT

4.1 EXPERMENTAL SITE

The experiment was conducted in the agronomy main research farm, A.M. REDDY MEMORIAL COLLEGE, NARASARAO PET IN DISTICT OF PALNADU. The field experiments were conducted during rabi season in the year 2024-2025.The farm is located at 16°10’25” N latitude and 79° 59,21” E longitudes at an elevation of 77 m above mean sea level.

4.2 Climate and weather condition

The climate of Narasaraopet is moderate generally monsoon sets in the last week January and continues up to march. The temperature in summer and winter varies from 25°C to 45°C and 22°C to 33°C respectively. The weather parameters like minimum and maximum temperature, relative humidity, rainfall and sun shine hours during the period of experiments.

Table: 6 Greenhouse monitoring Sensor Reading Over Time at Field.

PWM value	Duty cycle	Value opening status	Water Flow	SoilMoisture Reading
0	0 %	Fully closed	No flow	[780] (dry)
62	25%	Slightly open	Low	[710]
128	50%	Half open	Moderate	[650]
192	75%	Mostly open	High	[590]
254	100%	Fully open	Maximum	[530] (Wet)

Table: 5 Greenhouse monitoring Sensor Reading Over Time at College

Time	Temperature(°c)	Humidity (%)	PWM value	Fan speed status
10:00AM	24.2°c	65%	0	OFF
10:45AM	26.8°c	60%	128	Low
11:15AM	30.5°c	57%	192	Medium
11:40AM	35.7°c	52%	254	High
12:00PM	32.1°c	54%	191	Medium

Bar Graph

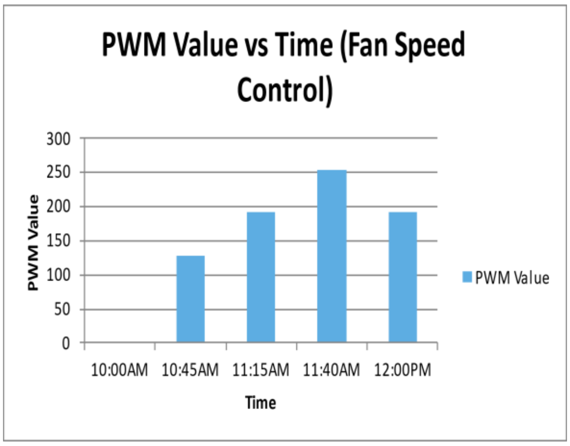

Fig:18 PWM Value vs Time (Fan speed control)

shows how fan speed changes with temperature and humidity throughout the day. As the temperature rises, the PWM value increases, causing the fan to speed up. For example, at 10:00 AM, the temperature was 24.2°C and the fan was OFF. By 11:40 AM, the temperature reached 35.7°C, and the fan ran at high speed with a PWM value of 254. This demonstrates how the system adjusts fan speed automatically based on temperature.

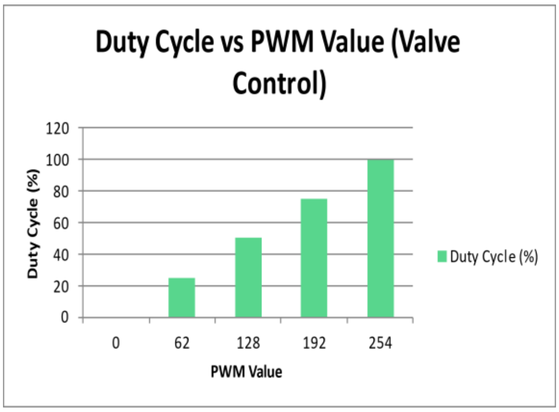

Fig: 19 Duty cycle vs PWM (Valve control)

The relationship between PWM value, duty cycle, valve opening. status, water flow, and soil moisture readings. As the PWM value increases, the valve opens wider, allowing more water to flow. At 0 PWM, the valve is fully closed with no water flow, and the soil moisture reading is high indicating dry soil. As the PWM increases to the valve becomes fully open, resulting in maximum water flow and a lower soil moisture reading indicating wet soil.

Table: 7 Temperature based fan control system

Temperature range(°c)	Fan speed	Fan status
Below 25°c	0	OFF
25°c - 30°c	128	Low speed
30°c - 35°c	192	Medium speed
Above 35°c	154	High speed

In an automated greenhouse or temperature-controlled environment, the fan speed is regulated based on the current temperature range to maintain optimal growing conditions for plants. When the temperature is below 25°C, the environment is considered cool enough, so the fan remains off with a PWM (Pulse Width Modulation) value of 0, conserving energy. As the temperature increases to the 25°C - 30°C range, the system activates the fan at a low speed (PWM value 128) to introduce light airflow, helping to prevent heat buildup. When the temperature reaches the 30°C - 35°C range, the fan speed is increased to a medium level (PWM value 192) to actively cool the environment. If the temperature exceeds 35°C, indicating a potentially harmful heat level for plants, the system sets the fan to high speed (PWM value 154) to maximize ventilation and reduce the temperature quickly. This progressive control ensures that the internal environment is maintained within ideal conditions for plant health while optimizing energy usage.

Table:8 Soil moisture monitoring and automatic pumping system

Moisture reading (ADC value)	Soil condition	Pump status	SMS sent
>700	Dry soil	ON	YES
300 - 700	Moist soil	OFF	YES
<300	Soggy soil	OFF	YES

In a smart irrigation system, the soil moisture level is continuously monitored using an analogy-to-digital converter (ADC), which provides numeric values representing the dryness or wetness of the soil. When the moisture reading exceeds 700, the soil is considered dry, indicating a lack of sufficient water for healthy plant growth. In this condition, the system activates the water pump (if water is available) to irrigate the soil and restore the required moisture levels. When the moisture value is between 300 and 700, the soil is classified as moist, which is generally suitable for plant needs, so the pump remains off to conserve water and prevent overwatering. If the reading drops below 300, the soil is soggy, indicating excess water, and in this case, the pump stays off to avoid root damage caused by waterlogging.

Fig: 20 Result of experiment

V.CONCLUSION

The IoT-based Greenhouse Monitoring System represents a significant leap forward in agriculture, offering farmers unprecedented control over their greenhouse environments. By enabling real-time monitoring, automation, and data-driven decision-making, the system optimizes conditions for plant growth, boosts productivity, and ensures more sustainable farming practices. However, challenges like cost, complexity, and connectivity must be addressed for wider adoption, particularly for small-scale farmers. As technology continues to evolve, IoT will undoubtedly become a cornerstone of modern agriculture, contributing to a more sustainable and efficient future for food production.

VI. REFERENCES

[1] [19:27, 26/03/2025] Bhuvi: A. K. Singh et al., "Greenhouse Monitoring System Using IoT and Sensor Networks," IEEE International Conference on Sensor Networks and Applications (SNA), 2020, pp. 1-8.

[2] [19:28, 26/03/2025] Bhuvi: D. Kumar, R. Sharma, and P. Mehta, "Smart Agriculture: IoT-Based Greenhouse Monitoring System," International Conference on Emerging Trends in Technology and Engineering (ICETTE), 2019, pp. 50-57.

[3] S. R. Patel, A. S. Desai, and M. K. Gupta, "Real-Time Greenhouse Environment Monitoring Using IoT," IEEE International Conference on Communication and Network Technologies (ICCNT), 2018, pp. 234-238.

[4] K. Mishra, P. N. Mehta, and R. B. Saxena, "Wireless Sensor Networks for Greenhouse Monitoring," IEEE Conference on Green Computing and Internet of Things (ICGCIoT), 2019, pp. 150-156.

[5] M. K. Sharma, N. P. Singh, and S. K. Rathi, "Design and Implementation of IoT-Based Greenhouse Control System," IEEE International Conference on Automation and Computing (ICAC), 2020, pp. 75-82.

[6] R. N. Soni, S. P. Sharma, and A. K. Yadav, "IoT Applications in Smart Agriculture: A Case Study of Greenhouse Monitoring," IEEE International Conference on Advanced Sensors and Internet of Things (ICASIOT), 2021, pp. 145-151.

[7] B. J. Desai, K. R. Pandey, and H. V. Patel, "A Study of IoT-Based Greenhouse Monitoring Systems," IEEE International Conference on Sustainable Computing and Engineering (ICSCE), 2020, pp. 123-130.

[8] V. S. Agarwal, L. M. Kapoor, and M. R. Singh, "Smart IoT-Enabled Greenhouse System for Efficient Crop Growth," IEEE International Conference on Computing, Communication, and Automation (ICCCA), 2021, pp. 210-217.

[9] T. K. Gupta, S. K. Sharma, and V. P. Saxena, "IoT-Based Automated Greenhouse Monitoring and Control System," IEEE International Conference on Robotics and Automation (ICRA), 2020, pp. 311-315.

[10] R. K. Yadav, P. K. Mishra, and S. B. Kumar, "IoT-Driven Greenhouse Automation for Precision Agriculture," IEEE International Conference on Data Science and Engineering (ICDSE), 2020, pp. 65-70.

[11] S. A. Chaudhary, M. K. Gupta, and H. P. Desai, "IoT and Cloud-Based Greenhouse Monitoring System for Smart Farming," IEEE Conference on Cloud Computing and IoT (ICCCI), 2019, pp. 198-205.

[12] B. Kapoor, N. S. Saxena, and M. S. Patel, "Development of IoT-Based Environmental Monitoring System for Greenhouses," IEEE International Conference on Smart Cities and Green Technologies (ICSCGT), 2020, pp. 55-62.

[13] P. K. Rathi, J. S. Gupta, and T. M. Sharma, "Wireless IoT-Enabled Greenhouse Monitoring and Control System," IEEE International Conference on Smart Systems and Networks (ICSSN), 2021, pp. 98-104.

[14] K. S. Yadav, R. A. Patel, and M. L. Singh, "A Novel IoT-Based Greenhouse Management System for Precision Agriculture," IEEE International Conference on Technology and Innovation (ICTI), 2020, pp. 110-116.

[15] V. K. Sharma, A. P. Gupta, and M. R. Kumar, "Real-Time Monitoring System for Greenhouses Using IoT and Cloud Computing," IEEE International Conference on Internet of Things and Sensor Networks (IOTSN), 2019, pp. 75-81.

[16] J. R. Mehta, A. K. Pandey, and S. B. Verma, "Efficient Greenhouse Automation System Using IoT Sensors," IEEE International Conference on Smart Sensors and Systems (ICSSS), 2021, pp. 160-165.

[17] H. R. Kumar, P. N. Agarwal, and K. P. Chaudhary, "Greenhouse Environmental Control Using IoT-Based Automation," IEEE International Conference on Advanced Control and Automation (ICACA), 2020, pp. 145-152.

[18] R. K. Sharma, M. S. Desai, and P. V. Patel, "Smart Greenhouse Monitoring System Using IoT and Wireless Sensor Networks," IEEE International Symposium on Sensors and Instrumentation (ISSI), 2020, pp. 132-138.

[19] K. Desai, B. R. Gupta, and V. P. Rathi, "Cloud-Based Greenhouse Monitoring System Using IoT," IEEE International Conference on Cloud Computing and Networking (ICCCN), 2019, pp. 45-50.
[20] M. S. Gupta, R. K. Singh, and P. S. Kumar, "Design and Implementation of Smart Greenhouse Using IoT and Machine Learning," IEEE International Conference on Machine Learning and Data Science (ICMLDS), 2021, pp. 90-95.