Integrated Hydroponics

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***Abstract*—The design and installation of a hydroponics monitoring system that can gather hydroponic system parameters, including temperature, water limit, pH level, and turbidity levels, is presented in this work. An ESP32 microcontroller and a number of sensors, such as temperature, turbidity, pH, and water level sensors, were used in the development of the monitoring system. In order to automatically activate the water or pump and drain the required materials into the plant basin of the hydroponic system, the ESP32 microcontroller collects and analyses data from the sensors. The Blynk app on a smartphone then allows the user to view the hydroponic parameters. If the parameter values are different from what is needed, the ESP32 microcontroller can turn them on automatically. The IoT interface and hydroponics monitoring system were successfully constructed and put into use. The experiments were compiled, and the data gathered and discussed. The hydroponic monitoring system was constructed using an ESP32 microcontroller equipped with temperature, water level, pH, and turbidity sensors. When necessary, the ESP32 automatically gathers and analyses sensor data to maintain pH or drain water into the hydroponic system's plant basin. Using his smartphone and the Blynk IoT app, the user can also monitor the hydroponic system's characteristics and, if required, operate the water, turbidity, and pH pumps.**

Keywords — hydroponics, plant, Blynk IoT, turbidity, pH, microcontroller

I. INTRODUCTION

The production of high-quality food for the world's population has long made agriculture the foundation of human civilization [1–4]. Agricultural methods must be intensified in order to meet the increasing demand for food while maintaining affordability and quality. One such invention is hydroponics, a branch of hydroculture that uses mineral fertilizer solutions dissolved in water to grow plants without soil [5–9]. Compared to conventional agricultural methods, hydroponics uses water and nutrient solutions as the growing medium, enhancing production through environmental condition monitoring. A hydroponic system allows plants to grow quickly and become a mass by keeping them in tubs where their roots float in nutrient-rich liquid. All of the necessary nutrients are directly supplied to plants in hydroponic systems by a nutrient-rich water-based solution. These systems can use a variety of techniques, such as growing plants directly in the solution or employing inert, non-soil media. When compared to conventional agricultural methods, hydroponic operations frequently provide superior yields since they are methodically regulated. To improve availability to fresh fruit, hydroponics has been used more and more in urban settings in recent years [10, 11]. At the same time, the Internet of Things (IoT) has become a disruptive force in the social, technical, and economic spheres. Internet of Things (IoT)-based hydroponics monitoring systems can be used to minimize losses, maximize output, optimize efficiency, and reduce time and effort [12,13].

An essential part of farming is keeping an eye on the plants' water levels, pH, temperature, and turbidity. Because of the convenience, accuracy, and efficiency that come with technological advancements, smart systems are used. The Internet of Things (IoT) is a network of interconnected computers that includes people, things, living things, and both mechanical and intelligent machinery. In addition to having identities, these devices may exchange data with computers and each other without requiring direct human or computer interaction. They are loaded with tools, online networks, and other equipment like sensors, and they can connect and communicate with others via the internet. They can also be automatically assessed and managed. In regions where the soil is insufficiently fertile to sustain crop production, this kind of irrigation is commonly employed. This project aims to address the issue of how to lessen the effort required of farmers to verify the ingredients that the plant requires without requiring their involvement.

Internet connectivity and sophisticated data analytics are being incorporated into commonplace items, such as consumer goods, automobiles, machinery, sensors, and utility parts. The way we live, work, and engage with the world is being completely transformed by this convergence.

The following features of the suggested system make it unique: Farmers can assess the efficacy of the hydroponic system by analysing sensor data they receive, monitoring and adjusting environmental parameters remotely thanks to automation and control components, integrating with other IoT technologies, being adaptable to the specific requirements of different crops and growing conditions, and optimizing resources.

II. MOTIVATION FOR PROPOSED WORK

This work is driven by the growing demand for automated, resource-efficient, and efficient agricultural solutions to overcome the difficulties in conventional farming. Although hydroponics, a soilless cultivation technique, provides a sustainable agricultural method, it necessitates ongoing monitoring and modifications to ensure ideal water quality and nutrient balance. Time-consuming and prone to human mistake, manual supervision can result in inefficiencies and possible crop losses. This project intends to streamline hydroponic farming by utilizing Blynk IoT and an ESP32 microcontroller to integrate IoT-based automation. This will reduce the need for manual intervention by offering real-time monitoring and remote control. Furthermore, the initiative aims to maximize resource utilization by guaranteeing accurate regulation of pH, turbidity, temperature, and water levels, which would enhance agricultural productivity and sustainability. This technology provides a scalable, flexible, and affordable way to increase productivity while cutting down on labour and resource waste, which is in line with the growing demand for intelligent and sustainable agriculture on a worldwide scale.

The primary goal of this work is to create an automated hydroponics monitoring system that continuously monitors important variables like pH, turbidity, temperature, and water level to guarantee ideal plant growth. The system eliminates the need for manual supervision by combining an ESP32 microcontroller with Blynk IoT to provide real-time remote monitoring and control via a mobile application.

By automatically regulating temperature, pH balance, and water clarity, the initiative seeks to maximize the use of water and nutrients while guaranteeing effective resource management. Additionally, by preserving a steady and regulated atmosphere and automatically adjusting the water, acidic, and alkaline levels in response to sensor data, the system is intended to improve crop development conditions. The project increases farmers' convenience by reducing manual intervention and enabling remote system modifications via IoT connectivity. A versatile and future-ready solution for smart agriculture, the system is also made to be scalable and adjustable, enabling adjustments for various hydroponic setups and crop-specific needs.

III. PROPOSED SYSTEM

Along with three auxiliary tanks for adjusting the water quality—an acidic solution tank to lower pH, an alkaline solution tank to raise pH, and a water tank to maintain the necessary water level—the system has a main tank that holds plants. A Wi-Fi module links the system to the Blynk IoT platform for real-time monitoring through a mobile application, while the ESP32 microcontroller controls sensor data and makes the required modifications automatically. Four essential sensors are integrated into the system: a pH sensor that maintains pH levels by turning on the pumps for acidic or alkaline solutions as necessary; a turbidity sensor that determines the clarity of the water; a temperature sensor that keeps track of the water's temperature; and an ultrasonic sensor that measures the water's levels and turns on the water pump as necessary. Through a mobile application, users may remotely operate the system, monitor readings, and receive notifications for significant changes thanks to the ESP32 microcontroller's collection and transmission of real-time data to Blynk IoT. In addition to optimizing resource use and minimizing manual labour, this automated hydroponics system guarantees a steady growing environment for plants.

An ESP32 microcontroller-based Internet of Things water monitoring and control system is depicted in the block diagram of the system (Fig. 1). Numerous sensors make up the system, such as a temperature sensor to track temperature variations, an ultrasonic sensor to monitor water levels, a turbidity sensor to evaluate water purity, and a pH sensor to test the acidity or alkalinity of the water. The ESP32 receives data from these sensors, processes it, and connects to the Blynk IoT platform for remote monitoring. A 4-channel relay module that manages several water pumps is likewise controlled by the ESP32. To maintain ideal water conditions, the ESP32 may turn on or off pumps based on sensor data.

For instance, a filtration system may be engaged if turbidity is excessive, or a pump may be put on to replenish the tank if the water level is low. Through a mobile application, customers may remotely monitor sensor data and operate the pumps thanks to the Blynk IoT platform. Applications including automatic irrigation, hydroponics, aquaculture, and smart water management are perfect for this technology.

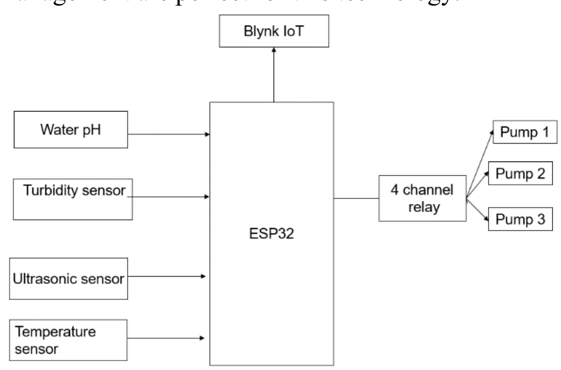

Fig 1 Block Diagram of proposed system

An Internet of Things (IoT)-based pump control and water quality monitoring system employing an ESP32 microcontroller is depicted in the circuit diagram in Figure 2. It incorporates a number of sensors, such as a turbidity sensor to determine the clarity of the water, a pH meter to measure the acidity or alkalinity of the water, a DS18B20 temperature sensor to track the temperature of the water, and an HC-SR04 ultrasonic sensor to measure the levels of the water. By gathering information from these sensors and sending it to the Blynk IoT application, the ESP32 enables users to remotely check the quality of the water. Furthermore, three water pumps are managed by the ESP32 via a relay module, which turns the pumps on or off in response to sensor data.

The ESP32 activates the appropriate pump to control water conditions when it detects specific situations, such as low water level, high turbidity, or an unbalanced pH. This system is perfect for applications like automated water management, aquaculture, hydroponics, and smart irrigation since it allows for both manual pump control and real-time monitoring using the Blynk IoT platform

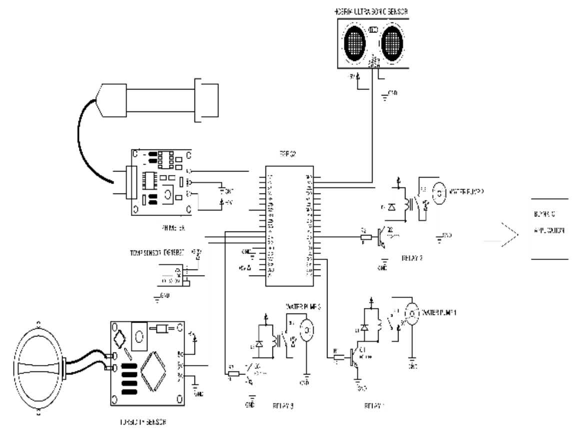

Fig 2 Circuit Diagram of proposed system

Blynk App

Smartphones are widely used in many different industries and have become an essential part of everyone's everyday life in the modern era. Specifically designed for the Internet of Things (IoT), Blynk provides tools for data display, storage, and visualization in addition to acting as a platform for remote hardware control. The Blynk Server, which mediates communication between smartphones and hardware, is essential to enabling seamless connectivity. The Blynk app connects to the hardware over Wi-Fi and displays an easy-to-use interface to users. By acting as the control centre, this program enables users to keep an eye on every sys

IV . HARDWARE SET UP FOR THE PROPOSED SYSTEM

To effectively monitor and regulate plant growth, a smart hydroponics system depends on a number of hardware elements. As the main component, the ESP32 microcontroller gathers data in real time from temperature, turbidity, pH, and ultrasonic sensors to guarantee the best possible water quality, levels, and clarity. Relay-module-controlled water pumps maintain water level and manage pH, while the Blynk IoT platform allows for smartphone-based remote monitoring and control. These elements work together to produce an automated, effective, and user-friendly hydroponic system that maximizes plant development while reducing the need for manual intervention. Figures 3 and 4 show the entire hardware configuration.

The peristaltic pumps that dispense water, nutrients, and pH-adjusting solutions are controlled by a combination of 4-channel and 1-channel relays in the hydroponic system. Based on sensor readings, the Arduino Mega can turn on or off pumps thanks to these relays, which function as electronic switches. The precise control of the hydroponic solution's composition is made possible by the assignment of each relay to a distinct function, such as water, nutrient solution, acid, or alkaline dispensing.

Real-time pH measurements from the pH sensor are crucial for preserving a steady and appropriate environment for crops that need particular pH values to grow healthily. Usually every few minutes, the Arduino Mega collects data from the pH sensor and uses a fuzzy logic method to analyse it. The Arduino activates the proper relays to engage a peristaltic pump, which dispenses either an acidic or an alkaline solution to balance the pH if the pH sensor determines that the solution's pH has changed outside of the optimal range (for example, becoming too acidic or too alkaline). To avoid abrupt pH changes that can stress the plants, this correction is accomplished gradually, frequently using several little doses. To maintain the pH within the optimal range, the system continuously monitors the feedback from the pH sensor and recalibrates as necessary. The pH sensor's automated feedback loop is essential for maintaining a steady and regulated environment in the hydroponic system, which improves plant development and health.

To make sure that plants have a steady and adequate supply of water, the ultrasonic sensor is utilized to track the water level inside the nutrient solution container. To determine whether the water level is within the desired range, the Arduino Mega periodically retrieves data from the ultrasonic sensor. The Arduino triggers a relay that is coupled to a peristaltic pump to add water if the water level falls below a predetermined threshold, signifying a low level. Only the appropriate amount of water is injected to attain the ideal level since the Arduino accurately controls the pump activation duration based on the current water level. Water is saved and overfilling is avoided with this method. Continuous monitoring by the ultrasonic sensor enables real-time modifications, which are essential for preserving the proper water volume for nutrient flow in the hydroponic system. The sensor ensures a steady environment by maintaining a steady water level, which promotes healthy plant growth and optimal nutrient delivery to the plant roots. A digital temperature sensor is employed to measure the system's temperature.

The ESP32 is a low-cost, low-power microcontroller with built-in Wi-Fi capabilities, making it an ideal choice for Internet of Things (IoT) applications. In this setup, the ESP32 connects the Arduino to a web server, allowing it to transmit sensor data, such as pH, water level, and nutrient concentration, to be accessed and visualized remotely. Once the Arduino collects data from the pH, EC, and ultrasonic sensors, it sends this information to the ESP32 module, which connects to a local Wi-Fi network. This integration of the ESP32 into the hydroponic setup thus enhances automation, monitoring, and user accessibility, creating a fully IoT-enabled hydroponic solution that supports efficient plant growth management. Turbidity sensor is used for monitoring the water quality using pH Sensor and ESP32.

For the hydroponic system to receive water, nutrients, and pH-adjusting solutions (either alkaline or acidic) exactly, peristalsis pumps are essential. These pumps are perfect for this use because they offer precise, regulated flow and can handle sensitive liquids without contaminating them, both of which are essential for preserving the right pH and nutritional balance in the water. Peristaltic pumps work by pressing a flexible tube with rollers or shoes, which forces the liquid inside to flow continuously through the tube. By preventing the fluid from coming into direct touch with the pump's moving elements, this design lowers the possibility of contamination and facilitates simple fluid management.

Based on sensor data from the pH, EC, and water level sensors, the Arduino Mega regulates the system's six peristaltic pumps, turning them on when necessary. The appropriate pump is turned on to administer the required acid or alkaline solution to return the pH to the ideal range when the system determines that it is too high or low. Similarly, the Arduino activates the pump to add extra nutrients to the water if the electrical conductivity (EC) sensor shows that the nutrient content is too low. Peristaltic pumps maintain the stability of the hydroponic environment by delivering precise and adjustable flow, which guarantees that all of the hydroponic solution's ingredients—water, nutrients, and pH modifiers—are supplied in the right amounts. For a nutrition film technique (NFT) hydroponic system to promote optimal plant growth, this degree of precision and control is essential.

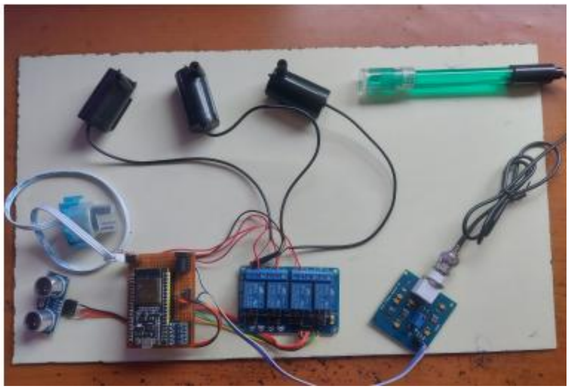

Fig 3 Arrangement of hardware components of proposed system

Fig 4 Hardware set up of the proposed work

A monitoring system using an ESP32 microcontroller and the Blynk IoT application was developed to evaluate the status of plants in a hydroponics system. Sensors collect the data, a microcontroller processes it, and the data are then transmitted to the Blynk server to be saved for further use. The user can employ that information to evaluate a plant's requirements. Using the Blynk IoT app, the user can view the hydroponics parameters as in Fig 5. If parameter values deviate from the required levels, the ESP32 microcontroller can automatically activate the water pumps.

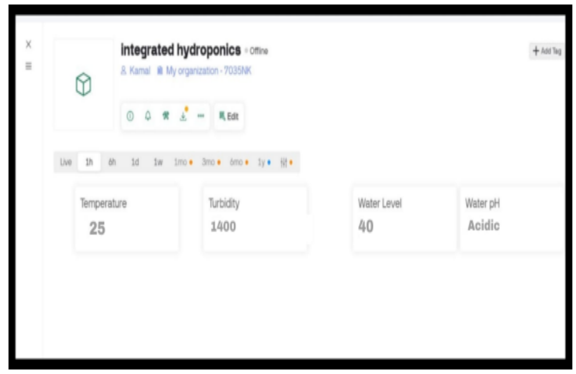

Fig 5 Realtime monitoring of system parameters in Blynk IoT server

V. RESULTS AND CONCLUSION

With the use of pH, turbidity, temperature, and ultrasonic sensors, the automated hydroponic system was able to effectively monitor and maintain the ideal water conditions. The ESP32 microcontroller distributed water and nutrients automatically and processed sensor data with efficiency. Blynk IoT was used for remote control and real-time monitoring, allowing for smooth system management. Plant growth and water efficiency were enhanced by the reliable operation made possible by the hardware and software integration. Overall, the goals of the planned work—automating hydroponic farming, decreasing manual intervention, and improving accuracy in water and fertilizer management requirements are satisfied. The designed automatic hydroponic system made sure that plants without soil might be grown effectively with the aid of the suggested system. Additionally, the suggested work used sensors and effective pumps to automate temperature, turbidity, and pH level control.

VI. FUTURE SCOPE

The smart hydroponics monitoring system developed using an ESP32 microcontroller and IoT technology successfully automates the monitoring and control of key hydroponic parameters, including pH, temperature, water level, and nutrient concentration. By integrating sensors with real-time data collection and remote control via the Blynk IoT application, the system ensures optimal growing conditions while minimizing manual intervention. The experimental results validate the system's efficiency in maintaining stable hydroponic conditions, reducing crop loss, and improving overall productivity. This automation not only enhances resource optimization but also promotes sustainable and precise agricultural practices. Looking ahead, the system can be further enhanced by incorporating AI-based predictive analysis to forecast plant health issues and optimize nutrient supply. Automated nutrient dosing tailored to different plant growth stages can improve yield efficiency. Additionally, expanding the system to support multiple crop varieties and integrating cloud storage for long-term data analysis will enhance its scalability. Energy optimization through renewable sources like solar power can make the system more sustainable, while features such as smart alerts and voice control can further improve user interaction. These advancements will strengthen the role of IoT in precision agriculture, making hydroponic farming more intelligent, efficient, and accessible.

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