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IOT Based Automated Indoor Hydroponic Farming System

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Abstract: Indeed, high yielding and high-grade crop production are crucial in modern agriculture, and smart farming technologies like vertical hydroponic farming can play a significant role in achieving these goals. The proposed vertical hydroponic system appears to be quite advanced and promising. Maintaining a cool and controlled environment is essential for optimal plant growth. Grow lights provide the necessary spectrum and intensity for photosynthesis, enabling plants to grow efficiently. Proper monitoring of water levels and moisture content ensures that plants receive an adequate supply of nutrients, preventing over or under-watering. The use of an Arduino controller with a keypad allows for user inputs and customization of the hydroponic system. Farmers can set parameters for water changes, flow rates, and indoor temperature to tailor the system to specific plant requirements. Monitoring and controlling various environmental parameters like light intensity, pH levels, electrical conductivity, water temperature, and relative humidity are essential for achieving the best possible crop yields and quality. Sensors and actuators help achieve this precision. The Internet of Things (IoT) integration allows for real-time data transfer and retrieval. Hydroponic Hardware prototype is proposed by combining these advanced technologies, the system can create an optimal environment for plant growth while minimizing resource wastage and maximizing yields. It's worth noting that as technology continues to evolve, there will likely be further advancements in smart farming systems.

1 Introduction

In the present situation, with the increase in population and the occurrence of natural calamities, agricultural production must be raised to ensure adequate food supplies. Vertical hydroponic farming is that comprises of cultivating crops in vertically stacked layers or columns instead of traditional horizontal farming methods. In this approach, plants are grown in a controlled environment without soil, with their roots employed in a nutrient-rich water solution. The idea behind vertical hydroponic farming is to maximize space utilization and create a more efficient and productive growing system.

It is a modernized and sustainable approach to gardening that allows for greater control over plant growth and yield. With hydroponics, plants can thrive in smaller spaces and be cultivated year-round, making it an attractive option for urban farming and indoor gardening. The key to successful hydroponics lies in the precise management of water, nutrients, and lighting conditions to optimize plant growth and health. Despite the high infrastructure cost of vertical hydroponic farming, it is gaining popularity due to its potential to revolutionize agriculture, particularly in urban areas and regions with limited arable land. As technology advances and becomes more accessible, vertical farming is likely to play an increasingly significant role in the future of sustainable food production, addressing food security challenges in a resource-constrained world.

IoT is vital to the computerization cycle, particularly in the automation of hydroponic systems. By linking the hydroponic system with IoT, automation becomes easily achievable. The cloud database acts as the central hub for the entire automation process, holding all information about the hydroponic system, including data from the crops and water tank. IoT sensors, installed in the hydroponic setup, monitor crucial parameters such as temperature, humidity, pH level, nutrient levels, water level, and light intensity. These sensors continuously collect data and send it to a central control system. The collected data is analysed through data analytics and machine learning (ML) algorithms, which help identify patterns, trends, and potential issues in the hydroponic environment. Erected on this analysis, the IoT system can automatically adjust and control the nutrient delivery to the plants, ensuring

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that nutrients received at the right time, optimizing their growth and health. IoT-enabled hydroponic systems also control the climate within the growing environment by regulating temperature, humidity, and ventilation to create an ideal growing environment for the plants.

With IoT, growers can remotely monitor their hydroponic farm using smartphones or computers, accessing real-time data, receiving alerts for critical conditions, and making system adjustments from anywhere, providing flexibility and ease of management. IoT can automate the watering process, ensuring plants receive adequate water while minimizing water wastage. For indoor setups, IoT can control the intensity and duration of artificial lighting to simulate natural light cycles and promote optimal plant growth. ML algorithms can analyze historical data to predict crop health and yield potential, helping growers plan harvesting and optimize farming practices. An IoT-based hydroponic system optimizes resource usage, including water, nutrients, and energy, leading to cost savings and reduced environmental impact. Integration with weather forecast data allows for adjustments in irrigation schedules based on weather conditions, further enhancing resource efficiency. The combination of hydroponics and IoT technology offers significant benefits, enabling more precise, automated, and data-driven farming practices. This integration can lead to higher yields, better crop quality, reduced operational costs, and a more sustainable approach to agriculture. As technology advances, IoT is expected to play a vital role in the future of hydroponic farming and smart agriculture in general.

The vertical Nutrient Film Technique (NFT) is a hydroponic system that uses a sloping or vertical channel to grow plants with their roots exposed to a thin film of nutrient-rich water. NFT is popular for its efficiency in water and nutrient usage, making it suitable for vertical farming setups where space is limited. The vertical NFT system combines the benefits of vertical farming and the NFT technique, allowing for increased crop density and optimized resource utilization. Developing an automated, and scalable cost-effective system for hydroponic farming can address challenges posed by unfavorable external environmental conditions during the summer. Here's a step-by-step implementation process: determine the available space and resources in each household for setting up the hydroponic system. Identify the basic needs of the households in terms of crops they want to grow and their nutritional requirements. Research and select the most suitable hydroponic technique for the targeted crops and available space. Common techniques include Deep Water Culture (DWC), NFT, and Vertical Farming. Ensure the chosen technique is user-friendly, easy to maintain, and requires minimal water and power consumption. Integrate automation components to monitor and control the hydroponic system efficiently.

Implement a sensor system to measure essential parameters such as temperature, humidity, pH, and nutrient levels. Set up an automated irrigation system to deliver nutrients and water based on plant needs. Use smart controllers to manage the system and optimize resource utilization. For indoor farming conditions during summer, use energy-efficient LED grow lights instead of continuous air conditioning. Implement a climate control system that regulates temperature and humidity within the hydroponic setup. Design a nutrient solution mixing and delivery system that provides the right balance of nutrients for optimal plant growth. Utilize a closed-loop nutrient recycling system to minimize waste and reduce the need for constant replenishment. Create a user-friendly interface to monitor and manage the hydroponic system remotely through smartphones or computers, providing real-time notifications and alerts for critical events.

These principles can be scaled up for larger farming operations, implementing centralized control and monitoring systems to manage multiple hydroponic units efficiently. Provide instructional guides and videos to help users set up and maintain the systems effectively, along with troubleshooting guides for common issues. Emphasize the use of eco-friendly materials and energy-saving technologies to reduce environmental impact. Promote water conservation using efficient irrigation methods and recycling systems. Encourage community involvement and knowledge-sharing among users to foster a supportive farming community, organizing workshops and training sessions to educate people about hydroponics and its benefits. A nutrient solution composition, with the right balance of macro and micronutrients, as well as attention to electrical conductivity, pH, and oxygen concentration, is essential for achieving optimal growth, yield, and quality of crops in hydroponic systems. Researchers and growers should carefully consider these factors to prevent stress symptoms and enhance crop performance in hydroponics. The combining hydroponics with automation and sustainable practices creates an effective and accessible solution for personal and large-scale farming, even in unfavourable environmental conditions.

The composition of the nutrient solution, electrical conductivity (EC), pH, and oxygen concentration play vital roles in the growth, yield, and quality of crops in hydroponic systems. It is clear from the provided information that the choice of nutrient solution can significantly impact crop growth and yield. For instance, Cooper's nutrient solution was found to enhance the yield of tomato cultivars Torques and Carmelo by 32% and 21%, respectively, when grown in NFT hydroponic systems [1]. Similarly, the tomato cultivar Lucy exhibited better vegetative growth and yield in Cooper's solution compared to Plantain solution [2].

The potassium content in the nutrient solution affects the pigment concentrations and beta carotene content of tomato fruits in hydroponics [3]. Maintaining appropriate potassium levels is crucial to achieve desirable fruit quality. The concentration of nitrogen and salinity in the nutrient solution can influence the vitamin C content of tomato fruits. An increase in these levels was found to gradually increase the vitamin C content [4]. Additionally, the ratio of nitrate to urea in the nutrient solution affects tomato yield in NFT hydroponic systems, with an increased nitrate ratio to

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urea resulting in a 25% increase in yield [5]. A nitrogen to potassium ratio of 1:1 (177.2 mg/l N and 188.7 mg/l K) in the nutrient solution resulted in larger tomato sizes [6].

Cucumber seedlings exhibited good growth results when grown hydroponically with Hoagland solution under LED light, showing a healthy appearance, high biomass, and high photosynthetic activity [7]. Lettuce also showed qualitative improvements under different nutrient solutions, with Hoagland solution being the most effective in hydroponics [8]. A reduction in nitrogen concentration (11, 9, and 7 milli eq. nitrogen/l) did not decrease tomato production nor significantly affect the diameter and dry and wet weights of tomatoes [9]. This article discuss the importance of nutrient solution composition, with the right balance of macro and micronutrients, as well as attention to electrical conductivity, pH, and oxygen concentration, is essential for achieving optimal growth, yield, and quality of crops in hydroponic systems. Researchers and growers should carefully consider these factors to prevent stress symptoms and enhance crop performance in hydroponics.

2 Block diagram representation

Figure.1, Show the schematic diagram demonstration of hydroponic system. A farming structure comprises of Total dissolved solids (TDS) and Potential of Hydrogen (pH) sensors to the Arduino Mega, they were tested and calibrated. The adjustment technique was completed by the maker's datasheet directions.

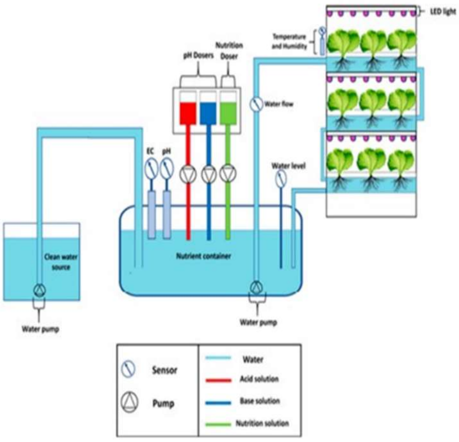

Fig 1: Hydroponic system model

The TDS and pH sensors are critical elements in maintaining plant health. The TDS sensor was standardised with dry, low, and high. TDS standardization fluids containing various TDS levels, while the pH sensor was standardized using multiple pH solutions, resulting in extremely precise and accurate data. The TDS sensor was then used to continuously monitor the TDS level, adjusting it as needed by adding water to lower the TDS or using the dosing pump to add nutrients to maintain the correct level.

2.1. Construction and working of TDS meter

The TDS worth of the water is estimated utilizing a simple TDS Conductivity sensor. The TDS value defines the water's purity. It can be used to test the quality of drinking water, hydroponic liquids, and other water-related products. Absolute Dissolved Solids (TDS) is an abbreviation for all out broke down solids (TDS). It shows the water's quality. High TDS signifies high dissolved solids in water and poor quality in general. TDS readings so define the water's purity. The sensors have been shown to deliver extremely precise data. Figure.2 Shows the TDS meter provide the permissible TDS values for various water sources.

Fig.2. Schematic of TDS Meter

The TDS (Total Dissolved Solids) measures how many milligrams of soluble solids are dissolved in one liter of water. This item acknowledges 3.3-5.5V wide voltage information and results in 0-2.3V simple voltage, making it appropriate for use with 5V or 3.3V control frameworks or sheets. The higher the TDS value, the more soluble solids are dissolved in water, and the less pure the water is overall. As a result, the TDS value can be used as a single point of reference for assessing the water's purity. This can be used to test and monitor water quality in home water systems, hydroponics, and other sectors. The Gravity Analog TDS Sensor will be connected to the Arduino Microcontroller. Since the temperature influences the TDS value. Waterproof Temperature Sensor will be added to gauge water temperature. TDS Sensor compensates for the reading with excellent calibration and accuracy using the recorded temperature. This item can be used in water quality applications like aqua-farming and home water investigation. You may handily make a TDS finder with this item to mirror the neatness of water and protect your well-being.

Figure.3, Shows the block diagram to represent the TDS meter with arduino interface. The TDS Sensor can be effortlessly connected to an Arduino. Connect VCC to 5V on the Arduino and GND to GND. Connect its Analog pin to any Arduino analog pin. In my case, we used Arduino Analog pin A1. TDS with pen arrangement need to provide to identify the TDS value. Based on cost effectiveness it is replaced TDS sensor arrangements with Arduino. TDS Measurement is straightforward through integration with Aurduino controller. The probe is not suitable for high water temperature beyond 55°C. Proper care should be maintained owing to container and transmitters are not waterproof.

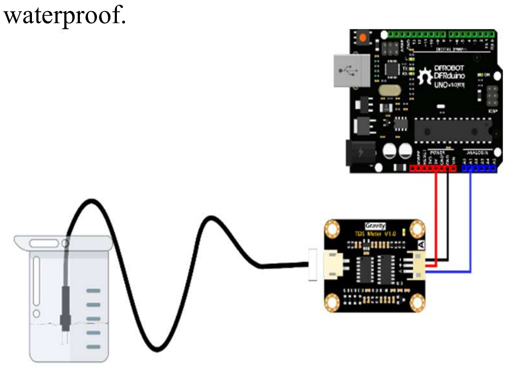

Fig 3: TDS meter to Arduino connection diagram

2.2 Working of TDS Meter:

The electric charge release between the two needles of a sensor test is estimated utilizing TDS sensors. When an excitation source is applied to a sensor probe immersed in water, the ions of dissolved materials transmit electric charges between the needles. The controlling unit estimates these electric charges, and the subsequent TDS esteem in ppm (parts per million) is shown. Figure. 4, Shows the schematic diagram representing working of TDS meter. Technically, total dissolved solids are tested in a laboratory, but if we want to do it ourselves, the best solution is to use an electronic TDS metre. The TDS reader measures the electronic conductivity (TDS) of water, calculates it, and displays the TDS value. This is expressed in PPM (Parts Per Million). The expert instrument has high precision and can send information to the control framework, yet the cost is costly for the conventional individuals. To this end, we have sent off a simple TDS sensor pack which is viable with Arduino, attachment and play, simple to utilize.

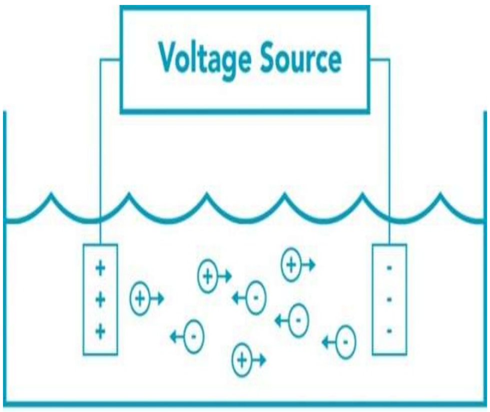

Fig 4: Working of TDS meter

Coordinating with Arduino regulator, you can construct a TDS identifier effectively to quantify the TDS worth of fluid. Because pure H2O water or distilled water does not conduct electricity, the result of a TDS reader immersed in totally distilled water will be "0" or a very low value if trace minerals are present. The charge of electrons that make up minerals permits them to lead power. In other words, mineral-rich water conducts more energy than mineral-free water. TDS pens are a common tool for determining TDS levels. In spite of the fact that it is economical and easy to utilize, it can't convey information to a control framework for internet observing and water quality analysis.

2.3. Connection and working of pH Sensor:

Figure.5, Show the block diagram representation of pH sensor with arduino interface. Utilize an outer exchanging power source with a voltage as near +5.00V as could really be expected. The better the exactness, the more exact the voltage. You should align the terminal with the standard arrangement prior to utilizing it consistently. The ideal temperature for the environment is around 25°C, the pH value is well-known and consistent, being near to measured value. The pH of standard solution should be 4.00 when measuring an acidic sample.

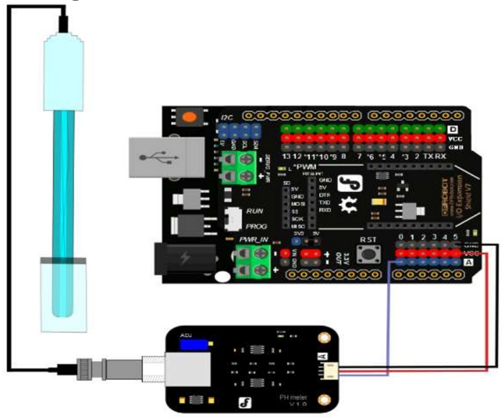

Fig 5: Connection of pH sensor

The pH of the solution would be 9.18 for measuring the alkaline sample. Subsection calibration is only done to improve accuracy. We had to wash the pH electrode with water before we could use it to measure different solutions. Deionized water is suggested. Associate the hardware as displayed in the graph, with the pH anode connected to the connector on the pH meter board and the pH meter associated with the simple port 0 of the Arduino regulator by means of the interfacing lines.

A procedure for calibrating a pH measurement system using an Arduino controller. When the Arduino controller is powered up, the blue LED on the board will turn on. Connect the Arduino controller to the sample code provided. This code likely includes instructions for reading pH values from a pH sensor. Place the pH cathode in a standard arrangement with a pH of 7.00, or short the BNC connector's feedback. Monitor the pH value shown on the serial monitor of the Arduino IDE. Record the pH value printed and compare it with 7.00. Adjust the difference to the "Offset" in the example code. For example, if the printed pH value is 6.88, the difference is 0.12. Replace "#define Offset 0.00" with "#define Offset 0.12" in the software. Place the pH electrode in a pH standard solution with a value of 4.00. Wait for a moment for the value to stabilize around 4.00. Once stabilized, the acidic calibration is complete, and you may measure the pH of an acidic solution. After properly washing the electrodes, we can immediately measure the pH value of an alkaline solution due to the linear properties of the pH electrode.

For improved precision, recalibrate the system using a standard solution with a pH of 9.18. Adjust the gain potential device to allow the value to settle at 9.18. After this standardization, we can measure the pH value of alkaline solutions accurately. This procedure ensures that the pH measurement system is accurately calibrated for both acidic and alkaline solutions, allowing for precise pH measurements across a range of solutions.

2.4 .Working of pH sensor

Figure.6, Figure 4: Shows the schematic diagram representing working of pH sensor. The pH metre will provided sufficient amount of time to establish after turning it on. Gently lift the electrode from the storage solution. Wash the anode with deionized water in a vacant waste container to clean it.

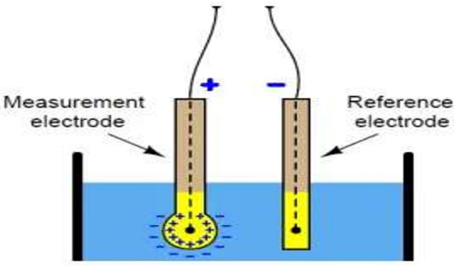

Fig 6: Working of pH sensor

To take out abundance water, tenderly flush and blotch dry with non-grating Kim wipes or sure wipes. To adjust the pH meter, we require three varieties coded standard cradle arrangements with pH. Place the terminals in a pH 7.0 cradle arrangement and trust that the pH estimation will settle at 7. On the off chance that the convergence of H+ particles inside the glass layer anode decides the required, expect the grouping of H+ particles inside the cathode and the cradle arrangement outside the terminal are something very similar.

The pH level in this example is 7. Rinse the electrode with distilled water and dry the blood with Kim wipes once the standard with pH 7.0 has been calibrated. If the predicted pH of the sample is acidic, select the pH 4.01 buffer solution, insert the electrodes in the buffer with a pH of 4.01, and push the calibrate button. Allow the pH value to remain stable at 4.01. pH will be less than 7. It means that H+ ions in electrode are lower than solution outside electrode position. If the predicted pH of the sample is alkaline, skip the previous step and go to this stage using the pH 9.21 buffer solution.

The uses of a pH sensor are numerous. It is used to determine the pH of soil in the agriculture industry. It's additionally used to assess civil drinking water and pools. In numerous compound and drug ventures, it is utilized to decide the pH worth of arrangements. The pH metre is also employed in the food industry, especially in the case of dairy products like cheese, curds, and yoghurts. The advantages of a pH sensor are: For long periods of time, provide high accuracy. Installation took up less room because it was easy to clean. The pH metre in your pocket is extremely accurate and inexpensive. If you've ever used PH metering, you'll know that pH values range from 0 to 14.

While pH 0 is very acidic, pH 7 is impartial, and PH 14 is incredibly alkaline. The calibration is the most difficult aspect of utilising the pH Sensor. Because the pH sensor is an analogue sensor, calibration is required because the output is voltage dependant. So we'll require an answer with a known pH Strength. There is an assortment of cradle arrangements available with a proper pH. To align the pH sensor, simply plunge the ph. Anode into an answer of known strength and see the perusing. You can stop rotating after the readings match, and the sensor will be calibrated. Since I had no cushion arrangements, I utilized milk to adjust the sensor. Milk has a pH range of 6.5 to 6.7. As a result, milk can be used for calibration. A pH meter is an electrical gadget that actions the causticity or alkalinity of fluids and semi-solids. The qualities of this marker were used to decide the acridity or alkalinity of different substances unequivocally. The pH metre is superior to other pH indicators for determining the pH of a liquid or semi-solid substance because it offers consistent values.

3 Practical Model of Hydroponic system

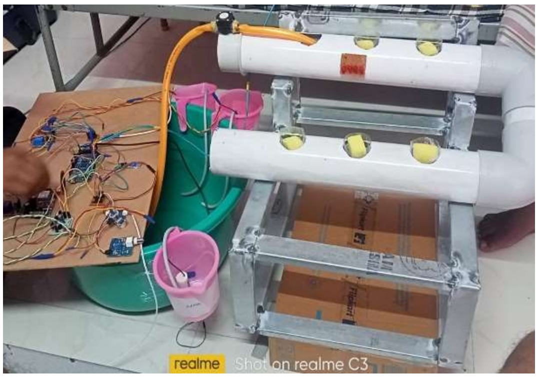

Fig.7. Practical Model of Hydroponic system

Figure.7, Shows the practical model of hydroponic system with IoT interface system. A unique box is created to store all of the dosing pumps. The electric wires of the dosing pumps can be linked to the relay and microcontroller through three holes on the back of the box. Figure.7. shows the supplement and pH control framework, as well as the holding box for the dosing siphons. Figure portrays the complete framework schematic.

Prior to involving the sensors in the plan, they must be adjusted. This figure depicts the system's overall circuit diagram. It represents all of the sensors and AC appliances connected to each other via the AC controller and power metre subsystem's connection.

There were two varieties of Arduino used: Arduino Mega and Arduino Uno. The controller is based on an Arduino Mega, while the power metre is based on an

Arduino Nano, and both communicate data via serial communication to the master Arduino Mega.

4 Flow Chart

The Figure.8.The flow chart discusses the operation and control of automatic hydroponic systems. Based on the sensor reading, the functioning principle of the whole automatic hydroponic system can be understood. Additionally, the pH can be adjusted with two dosing pumps that control either increase or decrease in pH values. This not only adjusts the pH and also selects the supplement pH answer for save the pH for the developing plant.

The YF-S201 Hall-Effect water stream sensor was associated with aligned to gauge the stream rate. The water flow sensor could reliably detect the flow rate by using a hall sensor to deliver pulses on the water fall and a microcontroller to count how much heartbeat to compute the stream rate. It was critical to guarantee the correct volume of water was added to the system when necessary, as well as to screen the all-out volume of water flowed in the framework.

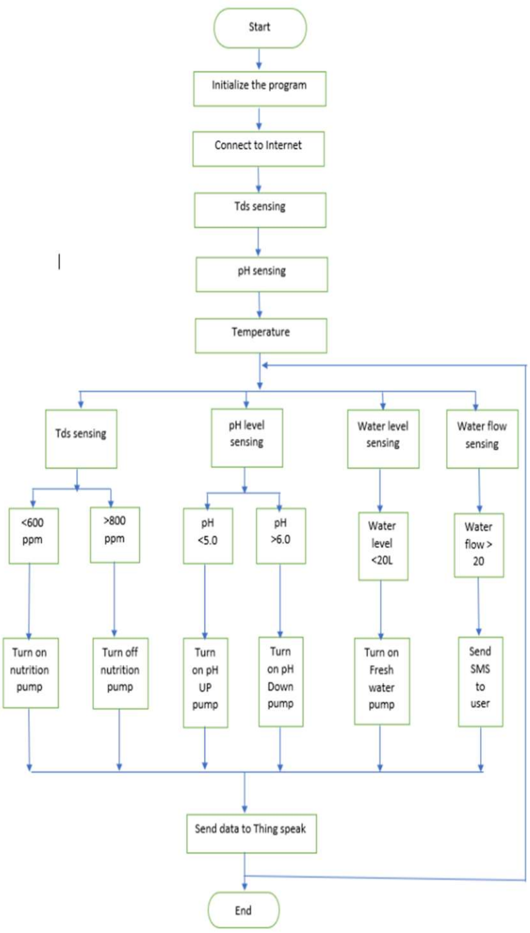

Fig 8: Flow chart of the automatic Hydroponic systems.

This allows us to calculate how much fresh water was refilled per day and on average per month to keep the water level in the system at the proper level.

5 Overall Block diagram of Hydroponic system with IoT interface

The Figure.9.implies an Overall model of Hydroponic system with IoT interface system arrangement. The data of the following parameters like the Total dissolved particles in solution, PH of the water, water level, Temperature, water flow, light intensity etc, will be collected from respective sensors. The collected data will be analysed by micro controller the practical values will be compared to the reference inputs given by the user. If the values are not as per user defined the required actions will be taken to make the values equal to refereed values. Then, at that point, the refreshed qualities will be transferred to the server by GSM module. The collected data will be analysed by micro controller the practical values will be compared to the reference inputs given by the user.

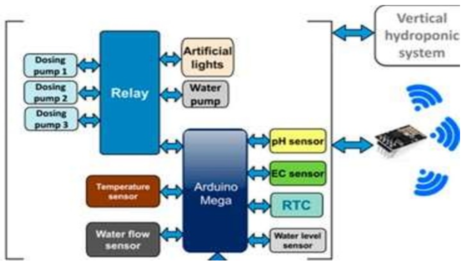

Fig.9. Overall model of Hydroponic system with IoT.

If the values are not as per user defined the required actions will be taken to make the values equal to refereed values. Then, at that point, the refreshed qualities will be transferred to the server by GSM module. The information can be received by the client from anyplace on the planet through method for web. This was accomplished by continually running the dosing pump for one minute, moving water from one bottle to another mL marked bottle. The dosing pump was found to be capable of delivering liquids in under a minute.

6 Output Results

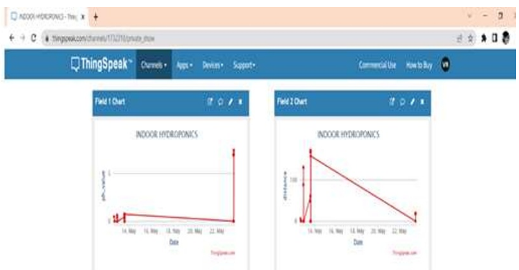

Fig.10. Outputs waveform of PH values with days of Things peak Web-interface on IoT platform.

Figure.10. Illustrates the outputs waveform of PH values over a number of days of Things peak Web-interface on IoT platform. The figure indicates the PH reading for a period of duration to access PH value and to regulate it.

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Fig.11. Outputs waveform water flow frequency with days of the Things peak Web-interface on IoT platform.

Fig.11. Illustrates the outputs water flow frequency over a number of days of the Things peak Web-interface on IoT platform. This will indicate water flow pressure for regulation and to control. Figure.12. illustrates the outputs TDS values over a number of days of the Things peak Web-interface on IoT platform. This will indicate TDS values for regulation and to control.

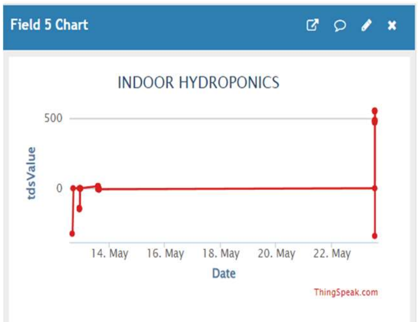

Fig.12. Outputs waveform of TDS values with days of the Things peak Web-interface on IoT platform.

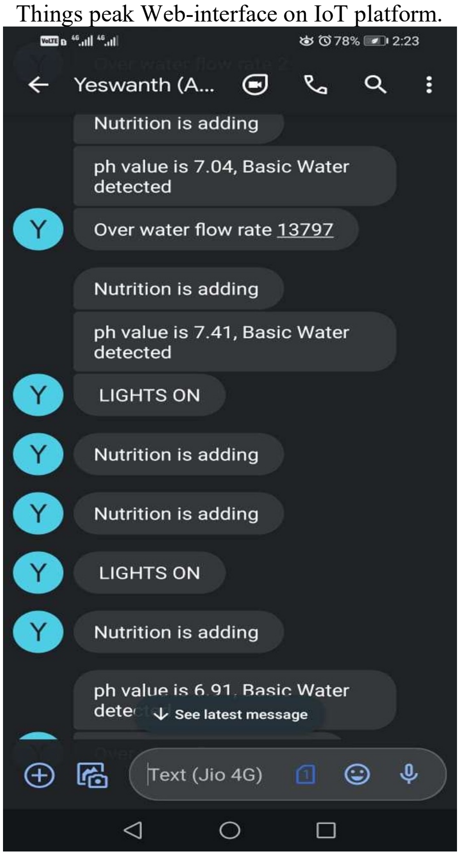

Fig.13. Mobile phone message alert.

Figure.13. demonstrates the status of the hydroponic system through mobile phone message alert and can control the operation.

7 Conclusion

The widespread adoption of solutions like the vertical hydroponic system can help meet local demand for fresh green vegetables while reducing reliance on imports. This wireless platform, integrated with the Thing Talk IoT platform, offers an easily accessible user interface allowing users to monitor parameters and receive SMS alerts if the pump fails. Moreover, it enables the study and tracking of growth for hydroponically produced plants, organic plants, and field plants. The system's properties, such as temperature, light wavelength, pH, TDS, and water levels, have been investigated and computed to ensure optimal growth conditions. Additionally, the fundamental structure of the system has been designed with low cost, efficiency, and adaptability for use in tiny indoor spaces. With these features in place, the vertical hydroponic system stands as a promising solution for home-based cultivation, promoting sustainability and self-sufficiency. A proto-type model is implemented with all sensor arrangement with incorporating IoT technology with control accessories.

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