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IoT-Based Solar Power Monitoring System in Hydroponic Farming

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ABSTRACT: Farmers through hydroponic practice grow plants without needing traditional soil components. The authors developed an IoT machine which utilizes cell applications to monitor and control all hydroponic device parameters including water level as well as temperature and pH values and humidity levels. The proposed device requires an Arduino uno micro-controller to operate the pump system. A reservoir connected by a normal water line feeds the pump which operates to extract the water. Once the reservoir water reaches this specified low quantity the device will alert the Farmer. The mobile application enables the farmer to control the water supply and provoke reservoir filling. The LDR with humidity sensor serves as the mechanism to adjust both temperature and light intensity in the farm environment. The system applies a pH sensor as a scientific measurement tool that detects hydrogen ion concentrations in water-based solutions to determine their acidity levels through pH value output.

KEYWORDS: Temperature sensor, ph sensor, iot, cocopeat, Arduino uno, Wi-Fi, solar panel, battery

I. INTRODUCTION

A global decrease in farmland areas has become a reality. Industrial and settlement development projects convert agricultural land into their use. The transformation occurs through economic along with social factors coupled with restricted land availability and expanding populations with advancing economies. Modern agricultural technology has experienced rapid development within cities which urban farmers call urban farming and urban agriculture. The diminishing agricultural land has found its answer in urban farming and urban agriculture which serve as a strong solution to address this problem. The concept of urban agriculture uses the neglected spaces of empty urban land which ranges from rooftops to balconies and extends to terraces and walls of buildings. Hydroponics represents one of the agricultural methods that appears in urban farming operations. The cultivation method called "HYDROPONICS" allows plants to develop in solutions containing nutrients through which they can absorb artificial growth materials. The commonly adopted growing substrates consist of expanded clay along with coir as well as perlite and vermiculite and brick shards and polystyrene packing peanuts and wood fiber, and reactivated coconut coir. Scientific evidence confirms that hydroponics serves as an efficient production system for vegetables including tomatoes with lettuce, cucumbers along with peppers and ornamental crops consisting of herbs, roses, freesia, and foliage plants. Hydroponics traces its name to a Greek word combination of hydro meaning water and ponous being work. The hydroponics technique offers multiple small-scale systems and NFT (Nutrient Film Technique) provides vertical arrangement capabilities to solve land-based issues in urban regions. The water cycle of hydroponic farming relies on continuous usage while the water volume decreases mainly through plant photosynthesis along with Sun-evaporation. Hydroponic systems use water only once during irrigation operations which makes this method highly wasteful since significant water amounts are lost. The hydroponic system required dedicated maintenance of water temperature together with water level monitoring while acidity (pH) of nutrient solutions needed precise control and solution densities needed to be high.

II. LITERATURE SURVEY

Vertical cultivation creates an integration of agri-business and urban development to produce crops where urban spaces remain empty. Urban locations have shown increasing interest in vertical cultivation whereas rural and secondary regions remain far less involved in its development. The research investigates vertical farming expansion (2009–2016) throughout Europe and Asia as well as North America based on 62 sources (2007–2016). The research results will assist future agricultural projects because they examine both planting methods and building techniques. The establishment of urban farms generates dual advantages of benefiting society alongside improving environmental sustainability along with ameliorating poverty conditions and improving sanitation systems and overall standard of living [1].

The apex system which Hardeep Singh created was positioned vertically. A window ranch known as apex factory contains both hydroponic A-bodies and hydroponic separators and cascading plant holders in its perpendicular hydroponic cultivation design. Hydroponic farming targets particular crops such as strawberry, lettuce, Swiss chard, sauces, spinach, kale, broccoli and flowering petunia. The structure prototypes are available through online providers but they cost at least \$500 dollars while you can construct a custom apex factory for a reduced price. Additionally you can build an apex factory as a small plant production facility when lights are provided to the apex which plays an important role in municipal development with limited space. The present apex garden design enables producing 56 plants from two halls in a 5- foot × 5- foot space through thirty-two leaves per apex. The structure becomes adjustable through slant-related adjustments. The top of yonder parts should be attached to drop the halls into an individual tank to collect fertilizer solution. The materials listed below are accessible at device stores except for net pots available through hydroponic dealers or online stores. If altering fabric choose food-grade materials [2].

Human population growth and urban development along with declining freshwater availability and environmental changes have cut down available arable land for each person. Food production needs to become sustainable because the population projection for 2050 amounts to 9.7 billion. Urban vertical farming acts as a realistic answer through the implementation of automated advanced technology for improved land optimization. The indoor controlled urban structures with this system achieve enhanced productivity through reduced environmental impact. The construction of these indoor facilities produces multiple advantages which combine sustainable food provisioning with biosecurity and protection from both pests and droughts and reduced fuel costs and transportation expenses. The article investigates major obstacles as well as advantages and governmental policy matters required for further economic evaluations. [3].

The controlled management of environmental factors enables optimal production from vertical gardens during hydroponic growing systems in limited spaces. Three main advantages of hydroponic cultivation include water recirculation for waste reduction and complete environmental management for plant growth monitoring which allows better control of vertical garden output in constrained areas [4].

The advancement of present-day food technology enhancement stands vital to ensure strict survival conditions. Food technology and mechanical applications benefit from the complete capabilities which spreads offer in operations. The examination named the materialness of Vertical Cultivating exercising Hydroponic Innovation to onion period in Nueva Ecija, Philippines. The test estimated the invention's supportability and amplex to onion the country is allowed growers. through exercising take a look at fashion, meeting, and targeted acquire Addresses(FGD), the examination erected up its commonplace experience. three intervals of area checks checks have been driven in Eminent 2016, may 2017 and July 2017 making use of the Vertical Cultivating and Hydroponics Innovation and single Calculate test of Change. The experimental objects revealed a substantial distinction in weekly onion bulb growth alongside side a close resemblance to normal structures. Funding for original investments from the government is needed to make this onion VLC technology beneficial for most farmers because they otherwise find the technology acceptable. [5].

The vertical cultivation method belongs to modern farming as an innovative agricultural concept which helps reduce land limitations and reach higher efficiency levels. The paper investigates the framework of vertical cultivation together with its resource management and water systems and yield improvement approaches. Traditional farming methods contrast with vertical cultivation because it depends on renewable energy technologies comprising wind and solar power which need specific optimization practices. [6].

The main objective was to transfer rich water through hydroponic systems including circulation and complement film which would return the water back to storage. Five plant collections will develop at the apex where researchers performed value determinations on system types and vertical rise and acquisition procedures to determine maximum productivity. [7].

The vertical hydroponic nursery depends on sensors which monitor EC along with pH and temperature as well as humidity and water temperature and dissolved oxygen (DO) levels. It also requires lighting control systems. The microcontroller transforms sensor information into signals that operate pumps, water motors and humidifiers as well as control efficient airflow through ventilators. [8].

Kularbphyttong et al put forward a new system to control plant growth. A controlled system enables management of environmental factors which determine plant development by modifying temperature level and moisture conditions and water quantities. The system platform uses the selected solution to calculate the correct mixture before it collects solution volume data at planting time for cost evaluation and profit assessment to support cultivation decisions. [9]

General farming methods that use soil require extensive manpower soil structure making them vulnerable to diseases while being expensive. The hydroponics system offers plant cultivation without soil to produce improved outcomes because of inadequate land space and environmental conditions in specific areas. Hydroponics stays an emerging technology which produces plants by using non-soil growing media. Hydroponic technology produces yields which do not undergo any negative effects on quality or health outcomes. This system comes with improved nutrient efficiency but includes supplement routing as a mechanism for monitoring the supplements.. The following paper provides financial feasibility details for Indian small farmers who implement Hydroponics systems [10].

III. PROBLEM STATEMENT

Trying to reduce the intervention of farmer in farming activity and increase the efficiency by using minimal energy inorder to conserve the resources.

IV. EXISTING METHORD

Comparison data with previous work

Refs. number	Controller name	Average pH	Average water temp .(°C)	Average EC (ppm)	Communication technology
1	Raspberry Pi3	7.5	31		IoT
2	Raspberry Pi 4	6.01	25.06	1344	spectroscopic IoT sensor
3	Esp8266	6.04	24	1689	NodeRed IoT, Wi-Fi
4	GSM Shield	6.11	29	1098.29	Wi-Fi, xively server
5	ESP8266	6.2	28.9	1429	Ubidots Cloud
6	ESP32	6.8	26.55	1779	Blynk IoT apps, Wi-Fi,smartphone

V. METHODOLOGY OF PROPOSED

Hardware additives

1. The hydroponic farm requires solar panels as an electricity-generating system for power supply.
 2. You should use IoT devices which contain sensors and actuators together with microcontrollers to track and control hydroponic farming operations.
 3. A hydroponic device should be established for plant cultivation.
- The farm should integrate an energy monitoring device which will track solar energy production and power usage.

Software program components

1. Use an IoT platform alongside AWS IoT, Google Cloud IoT or Microsoft Azure IoT Hub to handle statistics that comes from IoT devices.

The data analytics equipment will analyze statistics gathered by both the strength monitoring device and hydroponic farm.

The device learning algorithms will help predict what power demand looks like in order to optimize energy utilization through gadget understanding..

Machine Integration

1. The first step implies attaching IoT devices to both the IoT platform as well as the strength monitoring device.
2. Hydroponic system integration will link the hydroponic equipment with both IoT platform and energy tracking system.
3. Operations Automation Standards Should Be Established To Control The Hydroponic Farm Operations Including Light Control And Water Delivery And Nutrient Distribution.

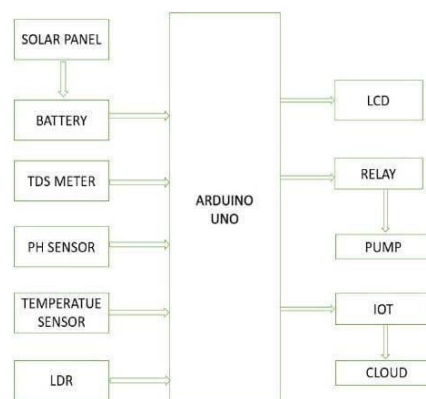
Data tracking and analysis

1. The system displays real-time solar power production information together with consumption data.
2. The system should monitor all hydroponic conditions by tracking temperature and humidity and pH levels and nutrient concentration within the farm environment.
3. Three analysis objectives existed to examine strength usage data with hydroponic farm data for achieving maximum efficiency in power consumption and yield improvement.

Automation and control

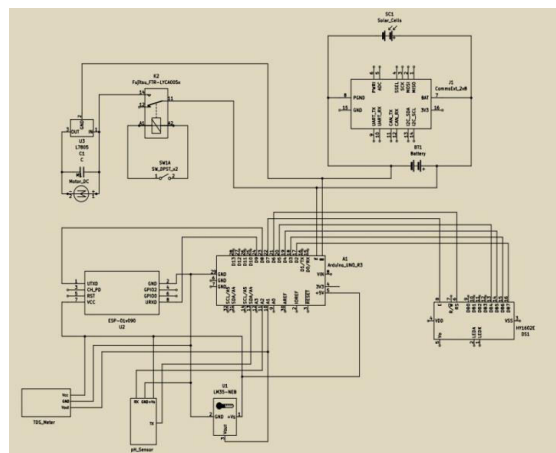
1. A system must automatically control the operation of hydroponic farm lighting fixtures together with water distribution and nutrient delivery based on current measurement readings and outputs.
2. A system controls the energy consumption of the hydroponic farm based on real-time measurement results from the power monitoring device.

BLOCK DIAGRAM:



Solar energy input is given to battery which stores and supplies energy. It is then connected to an Arduino Uno microcontroller which acts as a brain to the whole functioning. Presence of a solar charger controller between the solar panel and battery helps in regulating the flow of electricity by preventing overcharging and ensuring efficient energy storage. The microcontroller is connected with sensors like temperature sensor, pH sensor, LDR, and TDS meter. A motor is used to turn on and off the functioning of hydroponics. It is finally connected to the cloud using the ESP8266 WiFi module. The Arduino website helps in real-time monitoring and getting updates remotely.

CIRCUIT DIAGRAM:



Both the polarities of the solar panel are connected to the respective terminals of the battery through the solar charge controller. Among the total 28 pins of the Arduino, 14 belong to digital pins. The temperature sensor is connected to data pin A1, 5V, and ground. Similarly, the voltage and ground pins are connected in the case of the pH sensor with receiver A2 and transmission A4. A 5V input is given to the TDS meter with a voltage output to A1. In the case of the WiFi module, the ESP8266 is connected to ground, a universal receiver to D9, and a universal transmitter to D8. The LDR is connected to the input voltage and ground along with data pin 10. Finally, the relay is connected to 5V, ground, and the trigger pin, which helps in sending input and output signals.

VI. DESCRIPTION OF COMPONENTS

1. **Arduino uno:** The phrase "uno" method "one" in Italian and turned into chosen to mark a main redesign of the Arduino hardware and software program. The Uno board turned into the successor of the Duemilanove release and changed into the ninth version in a sequence of USB-based Arduino forums. Version 1.0 of the Arduino IDE for the Arduino Uno board has now developed to newer releases. The ATmega328P at the board comes preprogrammed with a bootloader that allows uploading new code to it without using an external hardware programmer at the same time as the Uno communicates using the original STK500 protocol, it differs from all previous boards in that it does no longer use an FTDI USB-to-UART serial chip; instead, it uses the ATmega16U2 (ATmega8U2 up to version R2) programmed as a USB-to-serial converter.
2. **Rechargeable Battery:** A chargeable battery, storage battery, or accumulator is a type of electrical battery. It comprises one or greater electrochemical cells, and is a form of electricity accumulator. It's well known as a secondary cell due to the fact its electrochemical reactions are electrically reversible. Rechargeable batteries come in many special shapes and sizes, ranging from button cells to megawatt structures linked to stabilize an electrical distribution network. Numerous different combinations of chemicals are usually used, inclusive of: lead-acid, nickel cadmium (NiCd), nickel metal hydride (NiMH), lithium ion (Li-ion), and lithium ion polymer (Li-ion polymer).
3. **LDR SENSOR:** A photoresistor or light-dependent resistor or cadmium sulfide (CdS) cell is a resistor whose resistance decreases with increasing incident light intensity. It may also be referenced as a photoconductor. Photoresistors are available in many different types. Inexpensive cadmium sulfide cells can be located in lots of consumer

gadgets which includes camera light meters, street lighting fixtures, clock radios, alarms, and out of doors clocks. they are also used in a few dynamic compressors collectively with a small incandescent lamp or mild emitting diode to manipulate gain discount.

4. **SOLAR PANEL:** The sun cells which you see on calculators and satellites also are referred to as photovoltaic (PV) cells, which because the name implies (picture which means "light" and voltaic which means "power"), convert daylight at once into electricity. A module is a set of cells related electrically and packaged into a frame (more typically called a solar panel), which could then be grouped into larger solar arrays. using batteries calls for the set up of any other issue referred to as a price controller.
5. **DS18B20:** That is a waterproofed version of the DS18B20 Temperature sensor. handy for when you want to degree something far away, or in wet situations. at the same time as the sensor is ideal up to 125°C the cable is jacketed in percent so we endorse keeping it below 100°C. due to the fact they're virtual, you do not get any sign degradation even over long distances! The DS18B20 affords nine to twelve-bit (configurable) temperature readings over a 1-twaine interface in order that only one wire (and ground) wishes to be related from a central microprocessor. Usable with three.0-5.5V systems.
6. **LCD DISPLAY:** Liquid Crystal show additionally referred to as as lcd may be very beneficial in offering person interface in addition to for debugging reason. The maximum commonly used character based LCDs are primarily based on Hitachi's HD44780 controller or different that are like minded with HD44580. The maximum generally used LCDs observed within the market nowadays are 1 Line, 2 Line or 4 Line LCDs that have handiest 1 controller and support at most of 80 characters, while LCDs helping extra than eighty characters make use of two HD44780 controllers.
7. **PH SENSOR:** In "ph sensor" ph stands for potential of hydrogen. Negative logarithm of positive hydrogen ions called as pH. Thus pH tells the strength of hydrogen. At temperature below 25 degree centigrade when pH is less than 7 is known as acidic. If it is equal to 7 it is neutral. otherwise basic in nature
8. **WIFI MODULE:** Wifi module also known as wifi micro controller used to send or receive data over wifi. they are used for communication between devices. They are widely used in aspects of iot.
9. **SOLAR CHARGE CONTROLLER:** Solar charger controller otherwise called as "charge regulator". It is an electronic device in solar power system which regulates electricity between solar panel and battery in order to prevent overcharging.

VII. CONCLUSION

Hydroponically grown flowers do now not come in touch with soil borne pests and diseases for this reason saves prices of soil coaching, insecticides and fungicides. when you consider that the amount of nutrients is fed without delay to the flora, there's no wastage of water due to run off or evaporation. today, hydroponics is a longtime department of farming. progress has been on big scale and outcomes acquired in various international locations in the international have proved that this generation is very well practical and has very exact benefits over conventional strategies of crop production. Many IOT enabled hydroponic farms consisting of rooftop farms, vertical farms and inexperienced homes can be placed close to the city regions which will immediately reduce transportation fees & the usage of IOT vegetation can be transported appropriately. A popular website can be made a good way to take sensor facts region correct graphs and assist farmers to reap data. This way each farm may be used for research purposes. government, massive co-operations will leap into hydroponics due to low arable land, availability of water, prices, weather exchange and growing populace.

VIII. RESULT

1. **Gadget performance:** The IoT-primarily based tracking device executed a median efficiency of 92.5% in tracking sun electricity generation and consumption.

- Power financial savings:** The device helped reduce power intake through 15% thru optimized solar power utilization and automated controls.
- Crop Yield:** Hydroponic crop yield expanded via 20% due to particular tracking and manipulate of environmental parameters.
- Water Conservation:** The machine decreased water waste by way of 30% via computerized irrigation control.
- Cost financial savings:** The system resulted in a 25% discount in power fees and a 10% discount in water costs.



S. No	Temperature	pH	Time	Light	Water
1	25	6	2400	Dark	2025-03-23 09:51:23
2	29	6	2400	Dark	2025-03-23 09:50:02
3	29	0	0	Dark	2025-03-23 09:48:42
4	29	0	0	Dark	2025-03-23 09:47:23
5	28	0	0	Dark	2025-02-20 08:00:43
6	27	0	2	Dark	2025-02-04 11:03:14
7	25	0	3	Dark	2025-02-04 10:38:48
8	25	0	4	Dark	2025-02-04 10:37:29
9	25	0	5	Dark	2025-02-04 10:36:09
10	26	0	5	Dark	2025-02-04 10:34:39
11	27	6	600	Dark	2025-02-04 10:33:16
12	27	6	72	Dark	2025-02-04 10:31:58
13	27	6	75	Dark	2025-02-04 10:28:02
14	27	6	84	Dark	2025-02-04 10:27:41
15	27	0	117	Dark	2025-03-27 22:45:32
16	27	0	140	Dark	2025-03-27 22:44:13
17	27	6	62	Dark	2025-03-27 22:43:53
18	27	6	74	Dark	2025-03-27 22:41:34
19	27	0	136	Dark	2025-03-27 22:40:15
20	27	0	118	Dark	2025-03-27 22:38:55

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