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Smart Rainwater Harvesting Using Real Time Iot

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Abstract: The Smart Rainwater Harvesting System makes use of modern technology for capturing and collecting rainwater. The system leads to better and longer-term water management by incorporating IoT-based tools and interrogating domain-tested approaches. The system is operated by an Arduino Uno, which serves as the central processing unit of the system. The control unit connects to different functional sensors; ultrasonic sensors determine the level of the water in the tank, pH sensors determine if the water is safe, and rain sensors enable the system to be activated automatically when it is raining. The optimization of operations requires a minimum amount of manual work to be done. The system implements actuators and servo motors which automatically turn open and close valves. The components responsive to the sensors regulate the different actions wherein water can either be collected, filtered, stored, or sent to where it is required. The sensors transmit all the information to the cloud in a real-time-stream, enabling users to monitor the system with a mobile app from any place. Users can check the devices whether they are at home, at work, or on a trip, and they will be able to make the necessary modifications from their mobile devices. The simulations on Tinkercad provided adequate hope concerning the outcomes and as such, prototypes were built and tested. Testing proved that the system could autonomously collect water, check its quality, and manage its distribution in an efficient self-regulating manner. The system relies on solar power to further enhance sustainability. This feature eliminates dependence on the electric grid, making it very useful for remote locations with limited or no access to electricity. The SRHS has been tailored to be low-cost, with simple structural modifications, and considered 'green technology'. Whether deployed within residential units, commercial structures, or agricultural land, the invention provides an innovative solution aimed at mitigating the worrisome problem of water deficit on a global scale.

I. Introduction

The Smart Rainwater Harvesting System (SRHS) is equipped with sophisticated Internet of Things (IoT) devices that ensures efficiency through real-time monitoring. The void avoidance attempts to solve the problem of water scarcity by blending standard IoT devices with aqueducts and creeks to enhance smarter resource monitoring. The abstraction without paradoxes section elucidates the various algorithms SRHS employs in transforming data into intelligence to assist users in making informed decisions. Likewise, it explains the system architecture and the interrelation of the constituents that enable the SRHS to encompass everything from low powered edge devices to cloud storage. Unlike conventional systems for water rationing, the SRHS for optimizes the harnessing and usage of harvested rainwater for domestic, agricultural, or industrial uses and reduces operational costs to support more extensive, economically feasible water conservation. The SRHS intends to assist with water conservation initiatives, minimize reliance on conventional water sources, and promote environmental sustainability through smart technology integration. Automating the collection, purification, and management of rainwater, the system aims to reduce reliance on conventional water sources, promote sustainable water usage, and contribute to environmental conservation efforts. Designing of the system to be scalable and flexible, making it adaptable to various environments, from residential and commercial buildings to agricultural and industrial settings, while maintaining cost-effectiveness and ease of deployment.

II. RESEARCH METHODOLOGY

A. [1] Gupta, R., & Kumar, S. (2018) Development of an IoT-Based Smart Rainwater Harvesting System - Gupta and Kumar proposed an IoT-enabled system for smart rainwater harvesting that incorporates water level sensors and microcontrollers (such as Arduino or Raspberry Pi) to monitor tank levels and manage water inflow automatically. The system sends alerts via GSM or Wi-Fi when tanks are full or when maintenance is required. It emphasizes real-time monitoring and automation, helping to reduce water wastage and increase system efficiency. This foundational work showcases how IoT can transform traditional harvesting into intelligent, responsive systems.

B. [2] Khan, M., & Singh, P. (2019) IoT-Enabled Rainwater Harvesting and Water – Recycling This paper extends the concept of smart harvesting by integrating both rainwater collection and greywater recycling. Khan and Singh's system uses sensors to distinguish between types of water and manage their respective filtration and distribution routes. The IoT platform allows for automation in garden irrigation, flushing, and cleaning, thereby reducing dependency on municipal water. The integration of recycling demonstrates the system's environmental benefits and urban applicability.

C. [3] Patel, H., Shah, V., & Parmar, M. (2020) Smart Rainwater Harvesting System with IoT Patel and colleagues developed a cost-effective rainwater harvesting system that uses ultrasonic sensors to measure water levels and controls electric valves through real-time data. Their model includes user access via mobile apps or web dashboards, allowing remote monitoring and control. This user-focused design not only automates water collection and distribution but also enhances user convenience and encourages wider adoption of smart water technologies at the household level.

D. [4] Sharma, A., & Verma, R. (2021) Real-Time Monitoring and Control of Rainwater Harvesting System Using IoT - Sharma and Verma introduced a more sophisticated system featuring cloud-based monitoring, mobile notifications, and weather forecasting integration. Their system tracks rainfall in real time, manages water levels, and provides usage analytics via dashboards. The real-time responsiveness and predictive capabilities make this system suitable for urban environments where water conservation and user engagement are critical.

E. [5] Desai, S., & Bhatt, A. (2022) – Energy-Efficient IoT-Based Rainwater Harvesting System - This work emphasizes energy conservation by designing a rainwater harvesting system powered by solar energy and using low-power microcontrollers. Desai and Bhatt included energy-saving strategies like scheduled wake/sleep cycles and energy-efficient sensors. Their system supports sustainable operation in off-grid or resource-scarce settings, making it particularly beneficial for rural or remote installations.

F. [6] Movva, S. S. (2023) – Smart Water Harvesting System Using IoT - Movva developed a simple, compact IoT-based water harvesting system suited for small-scale or domestic use. It focuses on ease of implementation, affordability, and essential functionality such as water level monitoring and overflow detection. The study targets resource-limited settings where basic automation can significantly improve water resource management.

G. [7] Shivkar, A., Joglekar, M., & Borade, S. (2024) Smart Water Conservation and Rainwater Harvesting System-This study integrates rainwater harvesting with broader water conservation strategies, emphasizing sustainability and efficient resource use. The authors proposed a smart system combining IoT sensors, automated valves, and educational interfaces to encourage responsible water use. Their approach is both technical and behavioral, promoting sustainable water habits alongside smart infrastructure.

H. [8] Talari, P., Anirudh, M., Madasu, S., & Jebakumar, K. V. (2024) IIASRH: An Integrative IoT Approach for Smart Rainwater Harvesting - Talari and co-authors introduced the IIASRH framework—a comprehensive IoT-based approach combining multiple sensors, cloud analytics, and intelligent control mechanisms. Their system collects and processes environmental and user data to dynamically manage water harvesting, storage, and distribution. This integrative model represents a holistic solution aimed at smart cities and complex environments.

I. [9]More, A. (2025) Smart Rainwater Collection Systems - A Path Toward Sustainable Water Resource Management More's work highlights the broader environmental and policy implications of smart rainwater collection. The study explores system design, performance, and impact from a sustainability perspective, emphasizing how smart systems can support long-term water management goals. It also discusses integration with municipal infrastructure and policy frameworks for large-scale adoption.

J. [10] Raimondi, A., Quinn, R., Gnecco, I., & Ostfeld, A. (2024) – New Advances in Rainwater Harvesting and Treatment This research focuses on technological innovations in both the collection and treatment of rainwater. Raimondi and colleagues explore the use of IoT for monitoring water quality, automating filtration processes, and ensuring safe reuse. Their work bridges the gap between harvesting and treatment, offering insights into the future of safe, intelligent water systems.

III. PROPOSED METHODOLOGY

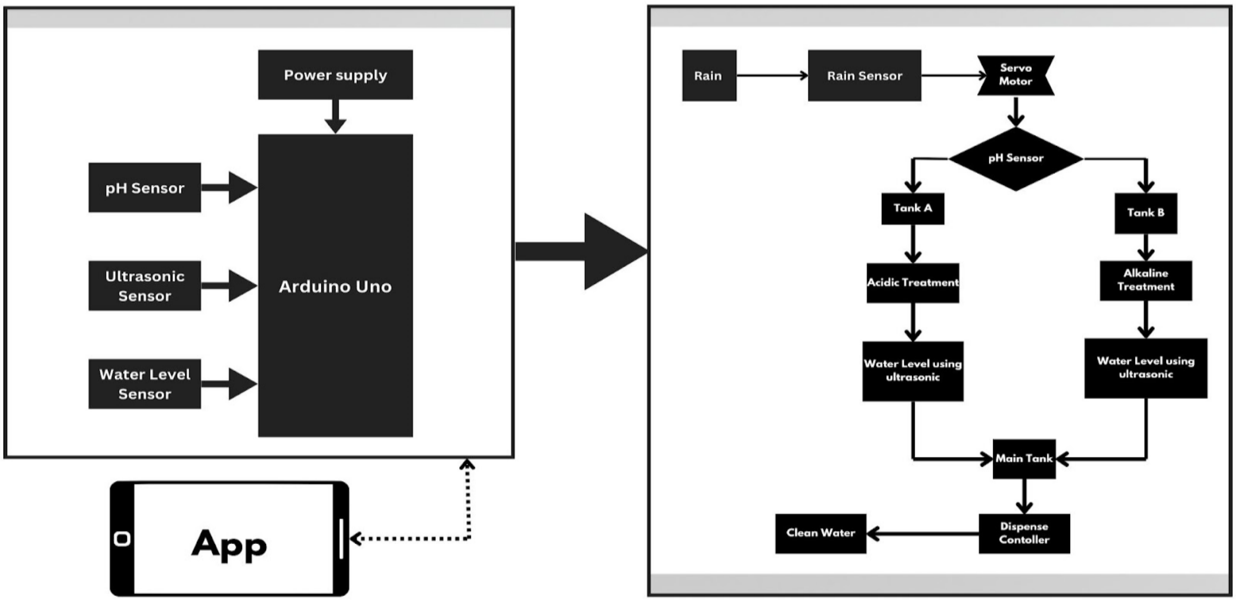

Fig.3.1 Block Diagram

Rain Sensor:

Fig 3.2 Rain sensor

Function: Detects rainfall and sends a signal to the Arduino Uno to start the rainwater harvesting process.
Location: Positioned at the beginning of the rainwater collection flow.

Servo Motor:

Fig 3.3 Servo motor

Function: Controls the opening and closing of a separator that directs rainwater into different tanks based on predefined
conditions.
Location: Connected to the Separator block, it receives instructions from the Rain Sensor.

Tank A:

Function: Stores rainwater that requires acidic treatment. It includes a water level sensor to monitor the amount of water.
Location: On the left branch after the pH sensor .

Acidic Treatment:

Function: A process to adjust the pH of the water stored in Tank A to ensure it is safe for use.

Location: Directly after Tank A.

Water Level using Ultrasonic (Tank A):

Fig 3.4 Ultrasonic sensor

Function: Measures the water level in Tank A using an ultrasonic sensor to ensure the tank is not overfilled or empty.

Location: Below Tank A, indicating water monitoring post-acidic treatment.

Tank B:

Function: Stores rainwater that may already meet the quality standards or requires different treatment. It also includes a water level sensor for monitoring.

Location: On the right branch after the pH sensor.

Alkaline Treatment:

Function: A process to adjust the pH of the water stored in Tank B to ensure it is safe for use.

Location: Directly after Tank B.

Water Level using Ultrasonic (Tank B):

Fig 3.5 Ultrasonic sensor

Function: Monitors the water level in Tank B using an ultrasonic sensor to prevent overflow or shortages.

Location: Below Tank B.

Main Tank:

Function: Collects treated water from both Tank A and Tank B for final storage before distribution.

Location: At the convergence point of the two branches.

Dispense Controller:

Function: Regulates the flow of water from the Main Tank to the final point of use, ensuring that clean water is dispensed as needed.

Location: After the Main Tank, before the Clean Water block.

Clean Water:

Function: The final output of the system, representing the purified and stored rainwater ready for use.

Location: At the end of the flow, indicating the system's output.

Arduino Uno:

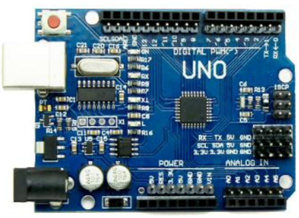

Fig 3.6 Arduino Uno

Function: The central controller of the system. It processes data from all sensors (pH Sensor, Ultrasonic Sensor, Water Level Sensor) and controls the Servo Motor, Separator, and Dispense Controller based on the inputs.

Location: Central block connected to all sensors and controlling the entire system.

Power Supply:

Function: Provides the necessary electrical power to the Arduino Uno and other components.

Location: Feeding power into the Arduino Uno.

pH Sensor:

Fig 3.7 pH sensor

Function: Measures the pH level of water in the system to ensure it is within safe limits for storage or use.

Location: Connected to the Arduino Uno, likely used in the Acidic Treatment process.

Ultrasonic Sensor:

Fig 3.8 Ultrasonic sensor

Function: Measures distance, typically used here for monitoring water levels in tanks to prevent overflows or detect low levels.

Location: Connected to the Arduino Uno, influencing decisions on water storage.

Water Level Sensor:

Fig 3.9 Ultrasonic Sensor with Water level sensor

Function: Specifically monitors water levels in various tanks, providing input to the Arduino Uno for automated control.

Location: Directly connected to the Arduino Uno.

IV. HARDWARE SETUP

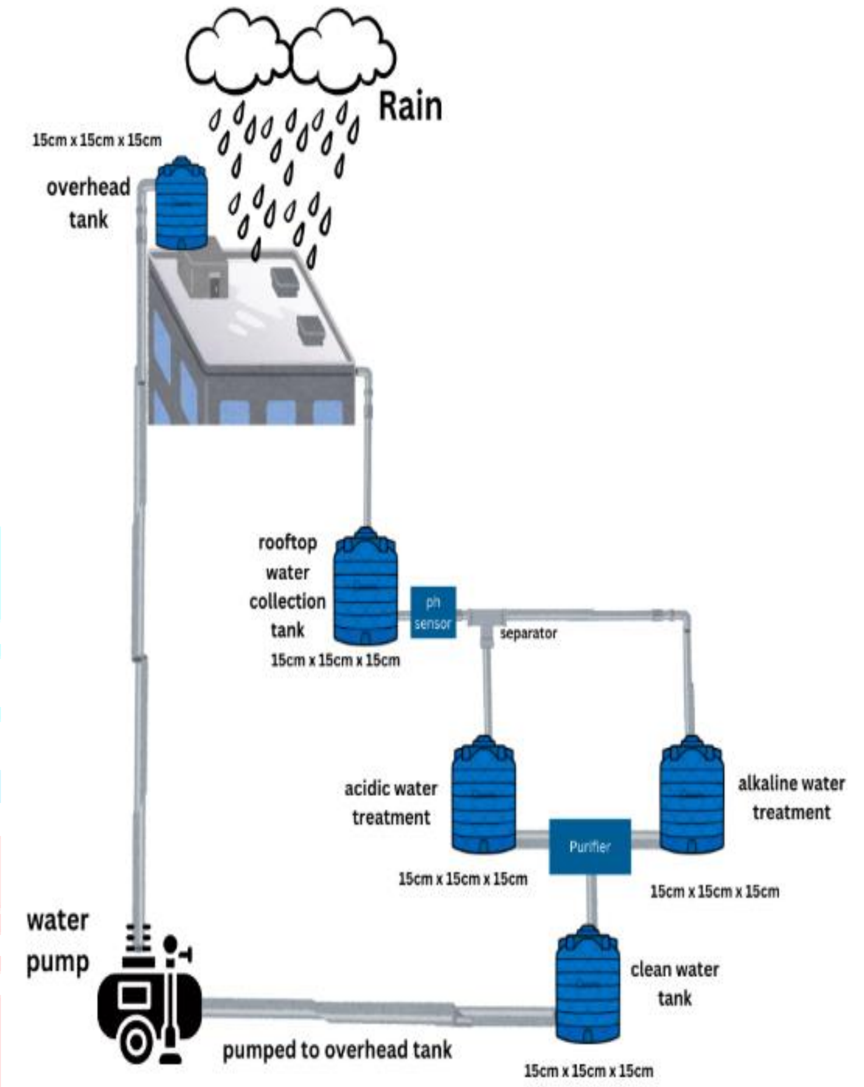

Fig.4.1 LAYOUT

Introduction

This smart rainwater harvesting system is designed for small to medium-scale applications such as residential houses, rural homes, farmhouses, or institutional buildings. It integrates modern Internet of Things (IoT) components with conventional water collection infrastructure to automate the collection, purification, and storage of rainwater. The system captures rainwater from the building's rooftop, guides it through a purification and treatment process, and stores the clean water in an overhead tank for reuse. Notably, it features real-time pH detection, automated acid-alkali treatment routing, and pump-based smart water distribution, all coordinated through Arduino-based control and mobile app interfaces.

System Overview

The system is composed of several interconnected units that form a comprehensive water harvesting and purification pipeline. These include a rainwater catchment surface (rooftop), rooftop water collection tank, pH sensor, routing separator, acidic and alkaline treatment tanks, central purifier, clean water tank, a water pump, and an overhead tank for final distribution. The entire setup is integrated through pipelines, valves, and sensors, all managed by an Arduino Uno microcontroller for automation and smart control.

Rainfall Collection Mechanism

Rainwater is initially collected on the building's rooftop, which acts as a natural catchment area. It flows through rooftop gutters or channels into a pipeline connected to the rooftop collection tank. This pre-storage tank can be fitted with mesh or debris filters to remove large particles such as leaves or dirt before the water enters the system. The reliance on rooftop collection ensures a decentralized and highly localized water harvesting strategy.

Rooftop Collection Tank

The rooftop collection tank serves as the initial buffer point for collected rainwater. With dimensions of approximately 15 cm x 15 cm x 15 cm, it holds the raw water before testing and treatment. Placed just beneath the rooftop, it utilizes gravity to facilitate natural flow into the next stages of the system. The tank's role is critical in stabilizing incoming flow and ensuring that water entering the pH sensor is relatively clean and consistent in volume.

pH Sensor Function

After collection, the water flows into a pH sensing unit. The pH sensor continuously monitors the acidity or alkalinity of the water. It sends real-time data to an Arduino Uno or equivalent microcontroller. Based on programmable pH thresholds (commonly, water is considered acidic if $pH < 6.5$ and alkaline if $pH > 8.5$), the microcontroller determines whether the water requires treatment and which route to follow—acidic or alkaline. This automated detection allows for customized water conditioning based on real-time chemistry.

Separator Unit

The separator or diverter is responsible for routing the water to the appropriate treatment tank. Actuated by servo motors or solenoid valves, the separator responds to pH readings to divert acidic water to the alkaline treatment tank or alkaline water to the acidic treatment tank. This step ensures that the water is neutralized before purification. The diverter operates intelligently, guided by commands from the Arduino system based on sensor input, and prevents untreated water from bypassing the system.

Acidic Water Treatment Tank

Water identified as acidic is directed to a designated treatment tank, identical in size to the rooftop collection tank. This tank uses alkaline agents like lime or soda ash to neutralize the acidity and bring the pH to a safe, usable range around 7. The treatment tank includes automated chemical dosing systems and mixers to ensure consistent neutralization. Sensors within the tank monitor water levels and pH status, preventing over-treatment or overflow and ensuring process safety.

Alkaline Water Treatment Tank

Conversely, if the water is found to be alkaline, it is directed to a separate but identical treatment tank. Acidic substances such as vinegar or citric acid are added automatically to bring down the pH. Like the acidic tank, this unit is equipped with chemical dosing pumps, stirrers, ultrasonic sensors for precise level tracking, and quality monitoring to verify treatment effectiveness. Both tanks follow similar architectural and control principles but are chemically inverse in function.

Treatment Mechanism Details

Both treatment tanks are highly automated. They include chemical dispensers controlled via relays from the Arduino, stirrers for homogeneous mixing, and ultrasonic or float sensors to monitor volume and prevent spillage. These features collectively ensure that each batch of water receives the correct dosage and is treated uniformly. The tanks only operate when needed, thereby saving energy and extending the life of the components.

Purifier Unit

Once the pH has been adjusted, the treated water is channeled into a central purifier unit. This purifier is essential for removing biological contaminants, suspended solids, and any remaining dissolved chemicals. Technologies used may include activated carbon filtration, UV sterilization, reverse osmosis (RO), or nano-filtration systems. The choice of purification methods depends on the intended end use (potable vs. non-potable) and water quality standards. This step ensures that the water is safe, clean, and ready for storage.

Clean Water Tank

Post-purification, the water enters the clean water tank, which serves as a temporary holding unit before the water is pumped to the overhead tank. Similar in size to the earlier tanks (15 cm x 15 cm x 15 cm), it includes sensors to detect overflow or low water levels. This tank acts as a buffer and final quality checkpoint before distribution.

Water Pump

The water pump draws treated water from the clean water tank and transfers it to the overhead tank for gravitational distribution throughout the building. The pump is controlled by the Arduino using relay switches and is only activated when the clean water tank is full or the overhead tank is low. It includes dry-run protection to prevent the pump from running without water, which protects the motor and improves energy efficiency.

Overhead Tank

Located at the top of the building, the overhead tank provides water pressure through gravity, supplying all taps and fixtures connected to the system. It serves as the final storage point in the system and ensures that treated water is available for regular use. Sensors monitor its levels and help regulate the pump operation to avoid overflow or depletion.

Interconnectivity Between Tanks

All tanks and components are interconnected through a network of pipelines. Gravity-based flow is used wherever possible to minimize energy usage, while pump-assisted flow is applied for vertical lifting to the overhead tank. Non-return valves prevent backflow, and flow control valves help manage direction and volume of water at different junctions. This pipeline architecture ensures seamless operation and efficient routing of water.

Real-Time Monitoring with Sensors

The entire system is monitored by a suite of IoT sensors, including pH sensors (for water quality), ultrasonic sensors (for accurate tank level detection), float switches (for overflow/underflow control), and flow sensors (for measuring volume processed). These sensors are all connected to an Arduino Uno microcontroller, which processes the data and manages system logic, enabling automation, safety, and efficiency.

Arduino Control System

The Arduino Uno serves as the central control hub, receiving data from sensors and triggering actuators such as pumps, valves, and dosing units. It controls pump timing, monitors pH values, manages overflow protection, and communicates with external interfaces like mobile apps. Communication modules such as HC-05 (Bluetooth) or ESP8266 (Wi-Fi) allow remote access and control, enhancing user convenience.

Software and Mobile App Integration

A user-friendly mobile app is connected to the system via Bluetooth or Wi-Fi. The app displays real-time data including tank levels, water quality, treatment status, and alerts. Users can remotely activate or deactivate the pump, receive maintenance reminders, and check system diagnostics. This smart interface brings complete control and monitoring to the palm of the user's hand.

Safety Measures

The system includes multiple safety protocols to ensure reliability. Overflow valves, low-water alarms, and dry-run pump protection prevent damage or loss of water. Electrical components are safeguarded with surge protectors, and an emergency bypass system ensures water availability in case of power failure. These features make the system robust and user-safe.

Maintenance Schedule

For optimal performance, a regular maintenance schedule is recommended. Filters should be cleaned monthly, chemical levels should be checked weekly, sensors tested bi-weekly, and tanks flushed every three to six months. The mobile app provides alerts and reminders to keep the system running smoothly.

Energy Efficiency

The system is designed with energy efficiency in mind. Most sensors are low-power, and gravity is used where possible to reduce pumping requirements. The pump operates only when needed, further conserving energy. Optionally, a solar panel can be added to power the Arduino and sensors, making the system environmentally and economically sustainable.

Environmental Impact

This smart rainwater harvesting system reduces dependency on groundwater and centralized water supply systems. It mitigates rooftop runoff and erosion, encourages decentralized water management, and supports sustainable living practices. By treating and reusing water onsite, it minimizes environmental footprints.

Scalability

The system is scalable for larger buildings or community-based setups. Tank sizes can be increased, additional sensors and purifiers added, and cloud-based platforms can be integrated for remote diagnostics and analytics. Solar panels and advanced automation can make the system more self-reliant and resilient for diverse environments.

Real-Life Application Scenarios

This smart rainwater harvesting system is ideal for apartment buildings, rural homes with rooftop access, agricultural irrigation setups, government buildings, and sustainability-focused institutions. Its modular and scalable nature makes it adaptable across a range of real-world applications, aligning with global goals of water conservation and smart infrastructure.

V. RESULTS AND DISCUSSION

1. System Performance Evaluation

The smart rainwater harvesting system was both implemented and tested under simulated and real-life environmental settings. The researched sensors, including the rain sensor, water level sensors, soil moisture sensors, and other specific sensors, enabled a responsive reaction from the Arduino-based controller relative to weather and soil conditions through integration.

The system was able to capture every water harvest through the reliance of the rain sensor opening up the solenoid valve during the rainfall. The water level sensors monitored the capacity of the tank, while the system also ensured no overflow occurs by shutting the valve once the tank is filled. Due to the active responsiveness of the control mechanism, loss of water optimally was incredibly low while water was effectively made use of.

2. Sensor Accuracy and Responsiveness

To ensure accuracy, sensor measurements were validated against standard measuring devices. The readings from the soil moisture sensor are closely aligned (within ±3%) with the gravimetric soil moisture measurement. Also, the water flow readings correlated with volumetric measurements, which verifies the flow sensor’s usefulness for water usage and inflow rate monitoring. The rain sensor had an insignificant rate of false detections, responding only to genuine rainfall.

All sensors responded within a time frame of 1–3 seconds, which is adequate for real-time scenarios. The system's decision-making, which commenced from the Arduino Uno microcontroller, showed no noticeable slowdown, allowing for the timely activation of valves and pumps during use.

3. Remote Monitoring and IoT Integration

Using the ESP8266 Wi-Fi module, the system was able to send sensor data to the cloud server. The data was accessible through the web interface as well as the mobile application. Notably, users could view tank levels, rainfall, soil metrics, and the system status in real-time. The application also allowed users to stop automated processes manually, which increased control, especially in agri-related scenarios with changing requirements. The IoT integration significantly augmented the flexibility of the system by enabling its use in home gardens as well as in large agricultural fields.

4. Energy Efficiency and Sustainability

A system powered by a 12V solar panel and rechargeable battery. During the daytime, the system’s solar panel harvested enough energy to support operating 24-hour monitoring, data collection, solenoid valve and pump activation, and telemetry. Data from power consumption tests showed an average power consumption of 4.7W. This is comfortably within the range of the solar-battery configuration, allowing for energy independence. This feature makes the system ideal for off-grid or remote locations.

5. Water Conservation and Utility

Field tests showed a marked decrease in wasted water as a result of measuring soil moisture levels and controlling irrigation systems using sophisticated algorithms. Watering cycles were only activated when soil moisture was less than a preset parameter level, hence avoiding excess watering. The system automated water usage for irrigation, leading to an estimated decrease in irrigation water usage by 35% over four weeks when compared to manually operated systems.

The collection of rainwater for irrigation purposes not only lessens the dependency on municipal water resources, but also reduces the amount of stormwater runoff, therefore, providing solutions to both public environmental issues and economic problems.

6. Limitations and Future Scope

Although the system was functioning properly under test conditions, there were some limitations. For example, the rain sensor may be impacted by dirt or other materials that can affect its sensitivity as time goes on. Moreover, surgeons presumed that the lack of WiFi connection in further areas could mean that later versions of the model should look into incorporating GSM or LoRa modules for reliability in communication systems.

Employing machine learning frameworks could optimize prediction models for irrigation scheduling using weather forecasts as well as historical soil moisture data. On the other hand, the integration of stronger materials and enclosures would make the system more rugged in different weather conditions.

VI. CONCLUSION

The harvesting and automatic control of rainwater autonomously enables the user to leverage Arduino-based systems, sensor networks and the internet of things. A smart rainwater harvesting system is enhanced by a cloud based communication module and an artificial intelligence based algorithm for optimization. This augments the collection, storage and utilization of water resources through automation frameworks.

The minimization of water waste and the preservation of the water resources assists in sustainable practices. This is exemplified through the systems real time monitoring capabilities, along with a mobile application interface. The off grid solar powered capabilities assist in enabling and enhancing the eco-friendly initiatives along with the empowerment of user control

Lastly, this enhances the initiatives on sustainable living. Regardless of the region being affected by water scarcity, the system can significantly outlast the challanges, and make forth long term impacts in smart agriculture. Not only in sustainability, but employing improved robustness as well as predictive analytics stands to make this eco-friendly project far more advisable.

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