Smart Air and Soil Condition Monitoring using Sensors and IOT Powered by Solar

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❖ **Abstract:-**

This project is mainly aimed to design to smart systems that continuously monitor air and soil conditions using IoT-based sensors. The system is capable of measuring important environment parameters such as NPK(Nitrogen, phosphorus, potassium), content,soil pH value , temperature, and some gases like Oxygen (O_2), carbon Dioxide (CO_2). All the measured values are displayed on an LCD screen for easy observation. Based on the soil conditions, the systems also suggests suitable crops, fruits, or vegetables that can be grown the main objective of this project is to help farmer and researchers to make better decisionsby improvingtheir agriculture sustainability , productivity and effective soil management.

I.Introduction:-

this project introduces smart agriculture designed to enhance farming and efficiency by modern technology and renewable energy.The main motive is to automate agricultural operations and reduce manual labor .The system is powered by the solar energy and uses various sensors to continuously monitor key environmental parameters such as soil moisture, temperature, and humidity. The collected data provides real-time insights into field conditions, enabling better decision making.

By integrating automation with agriculture, the project promotes sustainable farming practices and efficient use of natural resources. The system is sustainable for both small and large scale farms, helping farmer optimize operations. The control unit process sensor inputs and automatically manages irrigation and other farming tasks based on the reading, making the system eco-friendly, efficient , and smart.

❖ **Related work :-**

Several studies and projects have explored the use of solar powered smart agriculture systems to enhance energy efficiency and reduce reliance on traditional power sources. In earlier work, solar panels combined with rechargeable batteries were used to supply power to sensors such as soil pH,
Moisture, [NPK sensors] for continuous soil monitoring many researchers also integrated relay
modules to automate irrigation and control electrical loads based on sensors readings.These
approaches highlight how renewable energy can be effectively applied in agriculture support sustainable farming practices while reducing manual efforts and overall operating cost

❖ **System Design :-**

➢ **Controller:-**

The ESP32 is used as the main controller of the system. It handles input from various sensors, process the received data, and manages the overall communication and control logic of the system. Due to its built-in Wi-Fi capability and efficient processing power, it is suitable for IoT-based applications.

➢ **Other components:-**

Solar panel:- The solar panel is used to convert sunlight into electrical energy using solar cells. This cells generally made up of silicon and it generates electricity

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when exposed to sunlight by releasing electron s. The generated power is used to operate the entire system.

Charge controller:- the charge controller regulates the voltage and current coming from the solar parallel to prevent over charging of the battery. It also protects the battery from the deep discharge,
Which helps extended battery life. This ensure safe and efficient energy transfer from the solllar panel to the battery ant connected load.

Rechargeable battery:- The rechargeable battery is an essential part of the solar powered system. It stores the dc energy produced by the solar during day light hours. This stored energy is then used to power the system .

Controlling Module (Relay module) :-The controlling module commonly referred to as a relay module, is used to control high power devices using low power signals from the ESP32.

DC to DC Converter:- The DC to DC converter is used to convertand regulate the input voltages to the required levels for powering different components such as the ESP32 board, sensors and display units.

❖ **Working Of Components:-**

ESP32:- ESP32 is a micro controller that reads sensor data, control devices like Relay, and supports Wi-Fi and Bluetooth for wireless communication. It acts the main controller of the system.

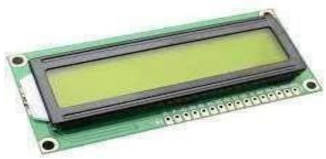
CO_2Sensor
(MH-Z19c) :-The MH-Z19c is a CO_2 sensor used to measure carbon dioxide levels in the air. It uses NDIR technology to provide accurate readings and supports UART and PWM outputs for easy interfacing. The sensor operates on 5v DC and can measure CO_2 concentration up to 5000 P.P.M

O_2Sensor (KE-25):- The KE25 is an oxygen sensor used to measure oxygen concentration in air. It works on electrochemical sensing and produces a small voltage output proportional to the oxygen level. The sensor does not need an external power supply and provides accurate readings with very low power consumption.

Soil NPK Sensor:- The soil NPK sensor is used to measure the levels of nitrogen, phosphorus, and potassiumin the soil. It helps evaluate soil fertility and nutrient content for better crop planning.
The sensor provides digital output using RS485 or MODBUS communication and operates on a DC power supply, Making it suitable for outdoor agriculture use.

Soil pH Sensor:- A soil pH sensor measures the acidity or alkalinity of the soil, which affects plant growth. It provides pH values from "0" to "14" and uses analog output that can be read by a microcontroller. This sensor helps in selecting suitable crops and is widely used in smart farming applications.

LCD Display:-The 16x2 LCD is a alphanumeric display that shows 16 characters on each of its Two lines. It operates on a 5V DC supply and can be interfaced with a Microcontroller using parallel or I^2C/ESP Interface. The display uses a 5x8. Matrix Character format.



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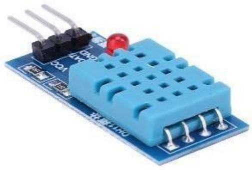
Temperature and Humidity (DHT-11):- The DHT-11 Sensor is used to Measure temperature And Humidity of the Surrounding Environment. It Provides Digital output, which Allows easy interfacing with the ESP32. In smart Agriculture Systems, this data helps in

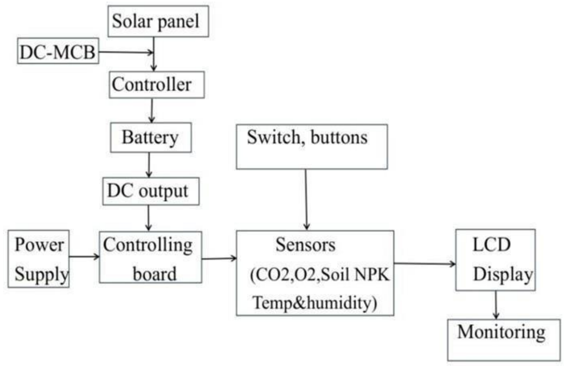


Monitoring Climate Conditions And can be used For Automated control irrigation or Ventilation.

Connecting wires:- connecting wires are used to create electrical Connections between Different components of the System. In a solar-powered Project, they transfer DC power from the Solar panel to The Charge Controller, battery, and load, ensuring proper and safe flow of electricity.

Solar Panel :- in this Project, the solar panel is used to Power The complete IoT-based Soil and Air Monitoring System. It Converts Sunlight into Electrical Energy, Which Is Stored in a Battery and Later Supplied to the Microcontroller, sensors, and IoT Module. This Setup allows the System to Work continuously even in remote areas without grid Electricity, making it self- Sustaining, eco-friendly, and Suitable for Smart Agriculture applications.

Block Diagram:-



The Purposed System is a Solar- Powered Monitoring and control unit designed for continuous and Efficient operation. The solar panel converts sunlight into DC electrical energy, which is first passed through a DC-MCB to protect the system from short-circuit and over current conditions. The protected power is then fed to a solar charge controller, which regulates the voltage and current to ensure safe and efficient charging of the battery . the rechargeable battery stores the generated solar energy and supplies power to the system during low light condition or at night . power from the battery is provided to the controlling board through a regulated power supply, ensuring that all electronic components receive a stable and required voltage. The controlling board acts as the central unit of the system and interfaces with various sensors such as CO_2,O_2, soil NPK, soil pH , and temperature and humidity sensors. This sensors continuously monitor soil and environmental parameters . switches and buttons are provided for manual control and system operation. The controlling board processes the sensor data in real time and displays the measured values on an LCD screen for easy monitoring . this system enables continuous observation of soil health and environmental conditions , helping farmers and researchersmake informed agriculture decisions. A use of solar energy makes the system eco-friendly , cost-effective , and suitable for long-term operation. Overall, the proposed system ensures reliable monitoring , efficient power management , and sustainable performance .

System Operation:-

The system operates as follows:

Solar power generation and protection: the solar panels converts sunlight into DC electrical energy required to operate the system. This power is first passed through a DC-MCB, which protects the circuit from over-current and short-circuit conditions. This protection ensures safe and reliable operation of the entire system.

Power Regulation and Energy Storage: The generated DC Power is regulated using a solar charge controller. The charge controller maintains proper voltage and current levels to ensure safe charging of the battery. The rechargeable battery stores this regulated energy and supplies power when sunlight is insufficient or during nighttime, allowing uninterrupted system operation.
Power Distribution to Control Unit: the stored energy from the battery is supplied to the controlling board through a regulated power supply. This ensures that all electronic components receive a stable and required voltage. Proper power distribution helps prevent damage to sensitive components.

Sensor Data Acquisition: various sensors such as CO_2, O_2, Soil NPK, Soil pH, and temperature-Humidity Sensors are used to collect real-time environmental and soil data. These sensors continuously monitor field conditions and send the collected data to the controlling board for further processing.

Data Processing and Control: The controlling board processes the sensor data according to the programmed logic. Switches and buttons are provided for manual operation when needed. Based on the sensor readings, suitable control actions can be performed.

Display and Monitoring: the processed sensor values are displayed on the LCD screen for easy monitoring. Users can observe soil and environmental parameters in real time. The clear display helps in timely analysis and better decision making for agriculture applications.

Advantages:-

- Solar powered renewable system.
- Continuous monitoring of environmental and soil conditions.
- Energy efficient with battery backup for uninterrupted operation.
- Automated control using sensors and relays.
- Real- time data display for easy observation.

Applications:-

- Smart agriculture and precision farming.
- Green house environment monitoring.
- Soil health analysis for crop planning.
- Environmental monitoring systems.
- Research and educational projects
- Farming solutions for remote areas.

Challenges and limitations:-

- Power management: solar energy depends on sunlight, so system operation can be affected during cloudy and rainy days.
- Sensor accuracy and calibration: sensor like Soil NPK, PH, CO_2 and O_2 Need proper calibration to provide accurate readings.
- Environmental conditions: dust, moisture, high temperatures, and rain may beimpact sensor performance and hardware safety.
- System integration: interfacing multiple sensors with the ESP32 may lead to communication and timing issues.
- Cost Constraints: using high-quality sensors and components can increase the overall project cost

Future scope:-

- Integration with IoT platforms for remote monitoring and advanced data analysis.
- Development of mobile or web applications for real-time alerts and control.
- Expansion with more advanced sensors to support precision farming.
- Implementation of AI/ML techniques for predictive analysis of soil and crop health.
- Large-scale deployment for smart agriculture and environmental monitoring.

Conclusion:-

This project demonstrates a smart IoT-based system for continuous monitoring of soil and air conditions. It measures important parameters such as soil NPK, pH, temperature, oxygen, and carbon dioxide in real time. The collected data is displayed on LCD screen, for enabling easy and quick observation of environmental conditions. Based on these readings , the system provides suggestions for suitable crops, fruits, or vegetables. The automated monitoring reduces manual effort, improves decision-making accuracy, and supports sustainable agriculture practices. By improving soil management and increasing productivity, the system proves to be cost-effective, reliable, and suitable for modern smart farming applications.

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