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Solar powered Air Purification and Environmental Monitoring System

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Abstract: Indoor air pollution poses a significant threat to human health and comfort, with pollutants such as dust, chemicals, and allergens contributing to respiratory problems and discomfort in indoor spaces. To address this issue, we propose a solar-powered smart air monitoring and purification system. Integrated with sensors for temperature, humidity, and air quality measurement, the system detects pollutants in indoor environments in real-time. Utilizing an ESP8266 Wi-Fi module, the system transmits data to the cloud for analysis and monitoring. When air quality surpasses predefined thresholds, the system activates a fan to improve ventilation and incorporates a HEPA filter for enhanced air purification. This proactive approach to indoor air quality management ensures healthier and more comfortable indoor environments for occupants.

Keywords: Indoor air pollution, solar-powered, cloud analysis, HEPA filter.

I. INTRODUCTION

Air pollution poses a significant global challenge, threatening both human health and the environment. Extensive studies have underscored its detrimental effects, ranging from respiratory illnesses to environmental degradation. Major contributors to air pollution include industrial activities, vehicular emissions, and household practices. Despite being less visible, indoor air quality is equally crucial, as it directly impacts human health and comfort. Given the gravity of the situation, there is an urgent need for effective solutions to monitor and mitigate air pollution levels, particularly within indoor spaces. This paper aims to address this issue through the development of a sophisticated air quality monitoring and control system. Central to our endeavor is the utilization of the ESP8266 microcontroller and a diverse array of sensors, including the DHT11 and MQ135, to provide real-time monitoring of temperature, humidity, and air quality. This comprehensive sensor suite forms the backbone of our system, enabling continuous assessment of indoor air conditions.

Automation plays a pivotal role in our project's design, inspired by findings from previous studies [2,3]. By establishing predefined thresholds for air quality parameters, such as pollutant concentrations, our system can autonomously activate a fan integrated with a HEPA filter to mitigate pollution when levels exceed acceptable limits. This proactive approach ensures prompt responses to deteriorating air quality, effectively safeguarding indoor environments against harmful pollutants. Moreover, our system's integration with the ThingSpeak platform facilitates remote monitoring and analysis, as demonstrated in related research [4,5]. Through this connectivity, users gain access to real-time air quality data via an intuitive web interface, empowering them to make informed decisions regarding ventilation and air filtering strategies.

This paper seeks to provide a cost-effective and efficient solution for indoor air quality management. The integration of advanced sensor technology, automation features, and cloud connectivity enhances the usability and effectiveness of our system in various indoor environments. By harnessing the power of real-time monitoring and automated control, our system contributes to creating healthier and more comfortable living spaces for occupants. Through continuous innovation and integration of cutting- edge technologies, we strive to address the complex challenges posed by air pollution and promote sustainable solutions for cleaner indoor environments.

II. METHODOLOGY

The methodology employed in our system is designed to ensure seamless integration and efficient operation of its various components. At the heart of the system lies a 22V solar panel, harnessing solar energy as the primary power source. This energy is stored in a series- connected battery setup, comprising three 3.7V batteries, to ensure continuous operation even in low light conditions or during night time. To regulate the voltage output, a 7812 regulator is utilized to maintain a steady 12V output, which is further stabilized to 5V by a 7805 regulator. This regulated voltage powers the ESP8266 microcontroller, which serves as the central processing unit of the system.

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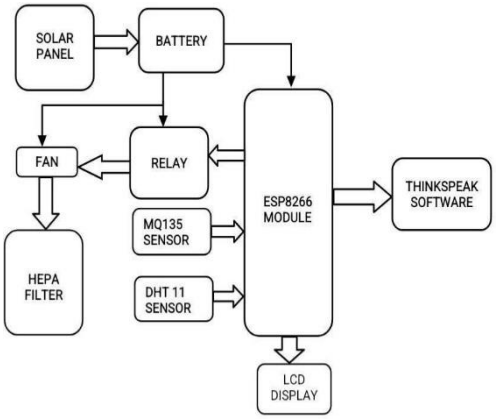

Fig.1 Block diagram

The ESP8266 is responsible for interfacing with the various sensors integrated into the system, including the MQ135 for air quality measurement and the DHT11 for temperature and humidity monitoring.

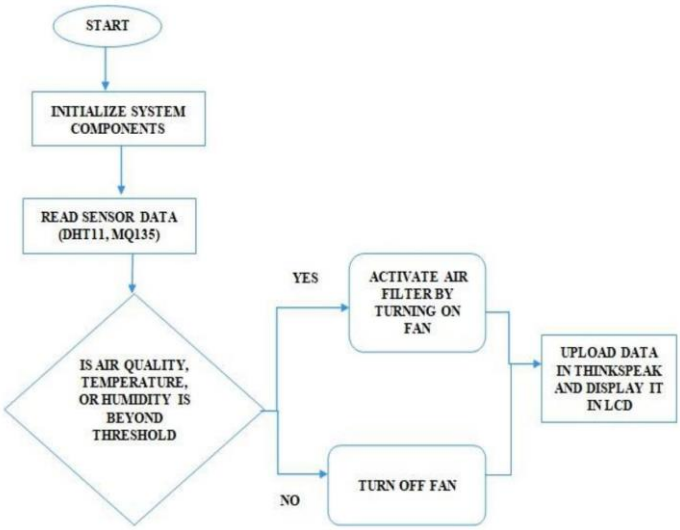

Fig. 2 Flow Chart

When sensor readings exceed predefined thresholds indicating poor air quality, the ESP8266 triggers the activation of a relay, facilitating the operation of a fan for air purification through a HEPA filter. This ensures that harmful pollutants are effectively removed from the indoor environment, promoting healthier living conditions.

In addition to local display of real-time sensor data on an LCD screen, the ESP8266 establishes a Wi-Fi connection to transmit sensor data to ThingSpeak, an online platform for remote monitoring and visualization. This feature enables users to access real-time air quality metrics from anywhere, empowering them to make informed decisions regarding ventilation and air purification.

Through the comprehensive integration of solar power, sensor technology, and wireless connectivity, our system offers an efficient solution for managing indoor environmental conditions. By ensuring optimal air quality and user comfort, it contributes to creating healthier and more comfortable living environments.

III. COMPONENTS

1) **MQ135 SENSOR** : The MQ135 sensor enjoys widespread popularity for its versatility in detecting a range of gases. including ammonia, nitrogen oxides, benzene, smoke, and CO2 in the air. It operates on the principle of resistance change due to gas concentration. When exposed to the target gas, the sensor's resistance decreases, allowing current to

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flow through, which can be measured to determine gas concentration.

TABLE I. SPECIFICATION MQ135 SENSOR

Parameter	Value
Operating Voltage	5 V DC
Operating Current	< 150 mA
Detection Range	10 – 1000 ppm
Target Gas	Air pollutants (e.g., CO, NH3, NOx, alcohol, benzene)

2) **DHT 11 SENSOR**: The DHT11 sensor is a low-cost digital temperature and humidity sensor that provides reliable measurements in various applications. It operates on the principle of capacitance change to measure relative humidity, while its thermistor element accurately measures temperature.

TABLE II. SPECIFICATION DHT11 SENSOR

Parameter	Value
Operating Voltage	3.3 V – 5 V DC
Operating Current	< 2.5 mA
Humidity Range	20% - 90% RH
Temperature Range	0°C – 50°C

3) **ESP8266 WI-FI MODULE**: The ESP8266 is a highly capable Wi-Fi microcontroller module known for its compact design and robust features. Equipped with a powerful 32-bit microcontroller, it enables seamless connection to Wi-Fi networks and supports TCP/IP communication protocols for internet connectivity. Its small size and versatile functionality make it a popular choice for integrating Wi-Fi capabilities into a variety of IoT projects.

4) **12 V FAN:** A 12V fan typically refers to a fan that operates at 12 volts. These fans are commonly used in electronic devices, automotive applications, and DIY projects.

5) **SOLAR PANEL**: A solar panel is an essential component of solar photovoltaic systems, harnessing sunlight to generate electricity efficiently. The solar panel used has multiple solar cells connected in series,produce an output voltage of approximately 22 volts under optimal sunlight conditions.

6) **RECHARGEABLE BATTERY:** A 3.7V rechargeable battery is a type of lithium-ion battery widely employed in portable electronic devices due to its compact size and energy efficiency. With a voltage output of 3.7 volts, these batteries are suitable for powering various gadgets such as smartphones, tablets, and digital cameras.

7) **LCD DISPLAY:** A 16x2 LCD (Liquid Crystal Display) module is a commonly used alphanumeric display that can show 16 characters per line and has two lines. It consists of a rectangular grid of 16 columns and 2 rows of character spaces, each capable of displaying alphanumeric characters, symbols, or custom graphics.

8) **HEPA FILTER:** HEPA Filter (High Efficiency Particulate Air) filters are widely recognized for their ability to trap microscopic particles such as dust, pollen, pet dander, mold spores, and bacteria. These filters are composed of a dense network of fibers that capture particles as air passes through them. HEPA filters are often rated to capture particles as small as 0.3 microns with an efficiency of 99.97% or higher, making them a key tool in maintaining clean and healthy indoor environments.

9) **ARDUINO IDE:** The Arduino IDE is a critical software platform for programming Arduino microcontroller boards, offering a userfriendly interface and robust features for code development. It simplifies the process of hardware programming with its intuitive interface and support for the Arduino programming language, which is based on C/C++.

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10) **THINKSPEAK:** ThingSpeak stands as a powerful IoT platform, empowering users to collect, analyze, and visualize data from sensors and devices. It provides cloud-based infrastructure for efficiently managing IoT data streams, along with tools for data visualization and analysis. With support for various IoT protocols and seamless integration capabilities, ThingSpeak facilitates communication between devices and applications.

IV. RESULT AND DISCUSSION

In the Solar powered Air Purification and Environmental Monitoring System, the challenge of ensuring clean indoor air is effectively addressed. Through meticulous integration of components, including the ESP8266 module, DHT11, MQ135 sensors, and HEPA filter, the system monitors and purifies indoor air in real-time. By connecting to Wi-Fi networks via the ESP8266 module, the system transmits data to ThingSpeak for remote monitoring. The DHT11 and MQ135 sensors accurately measure temperature, humidity, and air pollutants, enabling prompt intervention when poor air quality is detected. Activation of the air purifier, facilitated by the HEPA filter, ensures rapid improvement in indoor air quality. This comprehensive solution offers users a proactive approach to indoor air quality management, resulting in healthier living environments.

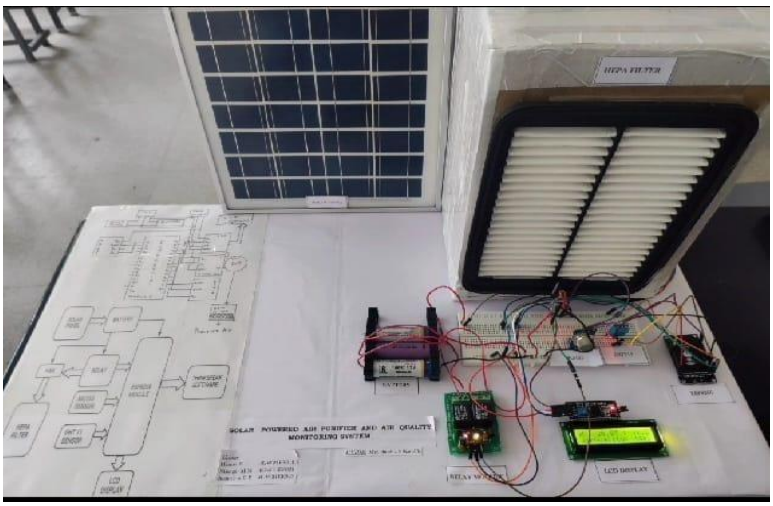

Fig 3. Implemented project model

The results for fan activation, determining air purification, are obtained based on two distinct cases defined by thresholds for air quality, temperature, and humidity levels, as follows:

TABLE III. CASES DESCRIPTION

Cases	Air quality in ppm	Temperature in °C	Humidity in %
1	<200	<33	<50
2	>=200	>=33	>=50

For Case 1:

- The air quality remains below 200 ppm.
- The temperature stays below 33°C.
- Humidity levels are below 50%.
- The fan remains off.

Fig.4 LCD result for case 1

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The figure 4 shows the LCD display result indicating an air quality reading of 64 ppm, which falls below the predefined threshold of 200 ppm for Case 1. Additionally, the temperature reading is recorded at 30.8°C, remaining below the threshold of 33°C, and the humidity level is noted at 44.2%, also below the 50% threshold. As all parameters remain within the specified thresholds, the fan remains off, indicating a favorable indoor environment.

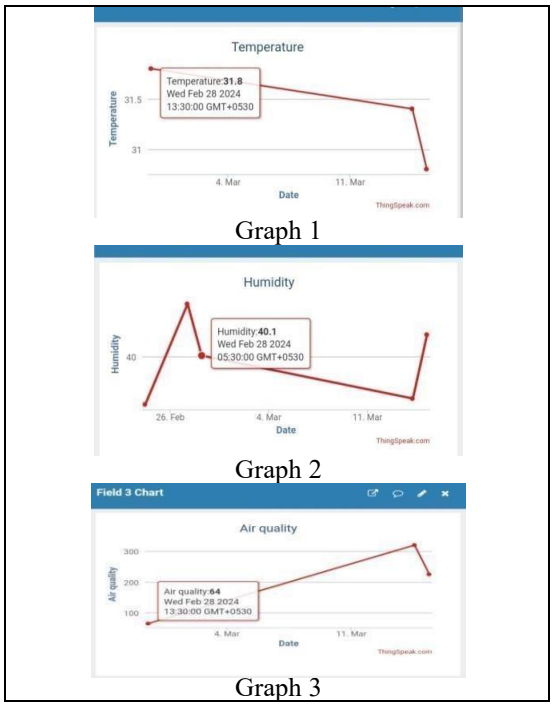

Fig.5 Visual analysis of Case 1

- From Graph 1 of Figure 5, the marked temperature value of 31.8°C falls within the acceptable range for comfort and is slightly below the predefined threshold of 33°C for Case 1. This indicates that the indoor temperature is within the desired range, contributing to a comfortable environment.

- From Graph 2 of Figure 5, the marked humidity level of 40.1% is within the acceptable range for indoor comfort and below the predefined threshold of 50% for Case 1. This suggests that the indoor humidity level is conducive to a comfortable environment and does not pose any discomfort to occupants.

- From Graph 3 of Figure 5, the air quality measurement marked at 64 ppm falls well below the predefined threshold of 250 ppm for Case 1. This indicates excellent indoor air quality, with minimal pollutants present in the air. Overall, the combination of these parameters reflects a favorable indoor environment in accordance with the criteria set for Case 1, ensuring comfort and well-being for occupants.

For case 2: The fan is activated for air purification if any parameter exceeds its predefined threshold.

- Air quality: >= 200 ppm
- Temperature: >= 33°C
- Humidity: >= 50%

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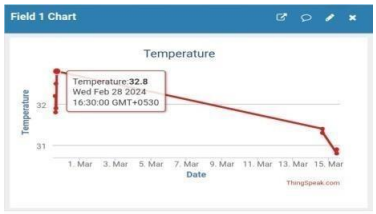
Fig.6 LCD result for case 2

The figure 6 shows the LCD display result for Case 2, where the parameters are analyzed to determine the status of the indoor environment. The reading indicates an air quality measurement of 470 ppm, which exceeds the predefined threshold of 200 ppm for Case 2, indicating the need for air purification. The temperature reading registers at 30°C, which is below the predefined threshold of 33°C for Case 2, and within the acceptable range for comfort. Additionally, the humidity level is recorded at 40.4%, which is below the predefined threshold of 50% for Case 2. With the air quality exceeding the threshold, and the humidity remaining below its threshold, the fan turns on for air purification, ensuring a healthier indoor environment for occupants.



Graph 1

Graph 2

Graph 3

Fig.7 Visual analysis of Case 2

- From Graph 1 of Figure 7, the marked temperature value of 32.8°C is slightly above the predefined threshold of 33°C for Case 2. This indicates a slightly elevated indoor temperature, which may border on discomfort for some occupants but remains generally acceptable.

- From Graph 2 of Figure 7, the marked humidity level of 40.1% falls within the acceptable range for indoor comfort and below the predefined threshold of 50% for Case 2. This suggests that the indoor humidity level is conducive to a comfortable environment and does not pose any significant discomfort to occupants.

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- From Graph 3 of Figure 7, the air quality measurement marked at 319 ppm exceeds the predefined threshold of 250 ppm for Case 2. This indicates a deterioration in indoor air quality, potentially due to increased pollutant levels. In response to this elevated air quality reading, interventions such as ventilation or air purification may be necessary to improve indoor air quality and ensure the well-being of occupants.

The exploration of these cases highlights the system's adaptability to varying environmental conditions. The establishment of specific thresholds for air quality, temperature, and humidity provides a framework for effective air quality management. The integration of automatic fan activation and deactivation in Case 2 underscores the system's responsiveness to fluctuating air quality levels. These findings emphasize the importance of intelligent control mechanisms in enhancing environmental monitoring and purification systems, ensuring sustained improvement in indoor air quality.

V. CONCLUSION

Our Solar-Powered Air Purification and Environmental Monitoring System presents a cutting-edge solution to indoor airquality management with numerous real-time benefits. By continuously monitoring temperature, humidity, and air pollutants, the system provides immediate feedback on the indoor environment's condition, empowering usersto take proactive measures for improvement. Leveraging IoT technology, users can remotely access and control the system, ensuring access to air quality data anytime, anywhere. This real-time monitoring capability not onlyenhances health and well- being by mitigating the risks associated with poor indoor air quality but also promotes environmental sustainability. By harnessing solar power for energy, the system reduces reliance on traditional energy sources, minimizing carbon emissions and contributing to a greener future. In essence, our project offers a holistic and efficient solution to indoor air quality management, addressing health concerns, promoting sustainability, and fostering healthier living environments in real-time.

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