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Air Purifier with IoT Monitoring using Renewable Energy

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Abstract: *This project integrates advanced air purification with sustainable energy generation to address environmental pollution and promote renewable energy solutions. It utilizes dual power sources solar panels and piezoelectric harvesting to ensure a continuous power supply. An MQ135 air quality sensor detects pollutants, triggering a HEPA filtration system powered by a DC fan to effectively purify the air. Additionally, a DHT11 sensor monitors temperature and humidity, providing comprehensive environmental data. A NodeMCU microcontroller facilitates real-time data transmission to the Blynk cloud, enabling remote monitoring via a user-friendly interface, while an LCD display ensures on-site visibility. This system offers a dual advantage: improving air quality while promoting renewable energy adoption, making it ideal for urban, industrial, and public spaces to contribute to a cleaner, greener future.*

Keywords: Air purification, renewable energy, environmental pollution, solar power, piezoelectric harvesting, HEPA filtration, air quality monitoring, MQ135 sensor, DHT11 sensor, NodeMCU, real-time monitoring, Blynk cloud, sustainable energy, smart air filtration, urban air quality

I. INTRODUCTION

Air pollution has emerged as a significant global challenge, posing severe risks to public health and environmental sustainability. Rapid industrialization and urban expansion have exacerbated air contamination, increasing the need for effective purification technologies. Simultaneously, the depletion of fossil fuel resources has driven the demand for renewable energy solutions. This project addresses both concerns by developing an innovative air filtration system powered by sustainable energy sources, ensuring continuous functionality while promoting eco-friendly practices.

The system employs dual power sources: solar energy as the primary supply and piezoelectric energy harvesting from footstep motion as a supplementary source. The combination of these technologies enhances energy efficiency and system reliability under varying environmental conditions. The harvested energy is stored in a rechargeable battery, enabling uninterrupted operation. At its core, the air filtration unit integrates a HEPA filter, activated by an MQ135 sensor that continuously monitors air quality. When pollutant levels exceed safe thresholds, a relay-controlled DC fan draws contaminated air into a filtration chamber, ensuring effective pollutant removal. A DHT11 sensor further enhances system functionality by measuring temperature and humidity, providing a comprehensive assessment of environmental conditions.

A NodeMCU microcontroller serves as the central control unit, managing sensor operations and data transmission. Real-time air quality metrics are uploaded to the Blynk cloud, enabling remote monitoring through an intuitive user interface. Additionally, an integrated LCD display provides on-site visualization of air quality, temperature, and humidity levels for immediate user awareness. By integrating advanced air purification with renewable energy generation, this system offers a scalable and sustainable solution to combat urban air pollution. Its application in industrial zones, public spaces, and smart cities contributes to a cleaner environment while promoting energy-efficient technologies for a sustainable future.

OVERVIEW

An advanced air purification system powered by renewable energy tackles air pollution and promotes sustainable energy use. The system primarily uses solar energy, supplemented by footstep-based piezoelectric harvesting for continuous operation. A HEPA filter efficiently captures pollutants, while an MQ135 sensor monitors air quality and activates a DC fan for filtration. Additionally, a DHT11 sensor measures temperature and humidity, providing a comprehensive environmental overview.Harvested energy is stored in a battery, ensuring uninterrupted operation. A NodeMCU microcontroller manages system functions, uploads real-time data to the Blynk cloud for remote monitoring, and displays local readings on an LCD. By integrating air purification with renewable energy, this system enhances air quality and supports eco-friendly practices, contributing to healthier urban environments.

II. LITERATURE REVIEW

According to [1], "A Survey on IoT-Based Air Pollution Monitoring System," explores the integration of IoT in air quality monitoring, highlighting the importance of various sensor technologies, system architectures, and data processing techniques. The paper underscores the advantages of using IoT for continuous, real-time data collection and suggests future improvements such as integrating predictive models to refine air quality forecasting and pollution control strategies. Challenges such as sensor accuracy and scalability in large deployments remain focal points for future research.

According to [2],"IoT-Based Air Quality Monitoring Systems for Smart Cities: A Systematic Mapping Study" provides a comprehensive comparison of 55 research proposals focusing on sensor accuracy, communication protocols, and power efficiency in smart city applications. This review emphasizes the necessity of integrating IoT systems into urban infrastructure to achieve real-time, scalable monitoring. It also highlights the challenges in implementing these systems, particularly around cost-effectiveness, data management, and achieving system robustness for widespread deployment in smart cities. The study proposes further research in enhancing system scalability and ensuring seamless integration into urban planning.

According to [3],"Air Quality Monitoring Using IoT: A Survey" extends the discussion by exploring the potential of combining machine learning algorithms with IoT to improve air quality forecasting. The study highlights advancements in sensor technologies, data transmission, and cloud-based data processing. A central conclusion is that integrating predictive analytics with IoT devices can enhance the overall effectiveness of air quality management. Future work is directed toward developing standardized protocols to ensure system interoperability and the reliability of data across diverse IoT platforms.

According to [4],"IoT-Based Air Quality Monitoring Systems - A Survey" provides a comparative analysis of various air quality monitoring systems, emphasizing cloud integration, mobile applications, and the challenges associated with high power consumption and limited network coverage. The study identifies critical weaknesses in the current systems and suggests optimization strategies to improve efficiency, data accuracy, and reliability for large-scale deployments.

According to [5],"The State-of-the-Art in Air Pollution Monitoring and Forecasting Systems Using IoT, Big Data, and Machine Learning" delves into the intersection of big data, machine learning, and IoT in enhancing air pollution forecasting systems. The review emphasizes the role of big data analytics in improving forecasting accuracy and identifies current issues such as data privacy and the need for lightweight algorithms for real-time data analysis. The paper also proposes integrating renewable energy sources to power IoT devices, ensuring sustainability in long-term monitoring efforts.

III. METHODOLOGY

For an air purification system integrated with **renewable energy solutions,** primarily leveraging **solar power** and **piezoelectric energy harvesting** to reduce dependence on traditional power sources. The system employs real-time **sensor data collection,** monitoring key environmental parameters such as **air quality, temperature,** and **humidity**. This data drives **automated actions,** including the activation of a **HEPA filter**and**DC fan** to maintain optimal air quality. The integration of a **Node MCU microcontroller** ensures efficient system management, while the **Blynk cloud platform** facilitates both **local and remote monitoring** for continuous access to environmental data. This approach

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ensures an **energy-efficient, automated,** and **remotely accessible**air purification system, optimized for both performance and sustainability.

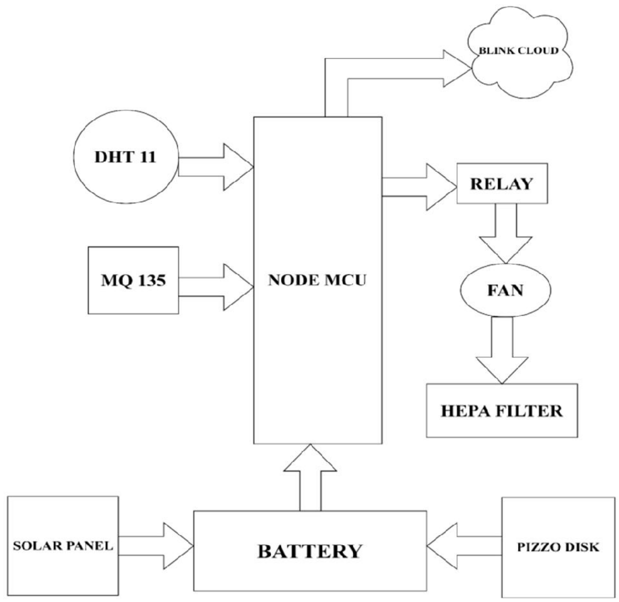

Figure 1: System Architecture of Proposed System

IV. IMPLEMENTATION

The proposed air filtration system is designed to integrate renewable energy generation with efficient air purification technology, ensuring sustainability and functionality. The system features dual energy sources: a solar panel and a piezoelectric disk. The solar panel harnesses solar energy during daylight, while the piezoelectric disk generates power from footstep motion, particularly in high-footfall areas. The energy generated from both sources is stored in a rechargeable battery, providing a consistent power supply to the system components. The air purification process is initiated by an MQ135 air quality sensor, which continuously monitors the surrounding air for pollutants. If the air quality falls below a predefined threshold, the NodeMCU microcontroller activates a relay, which powers a DC fan. The fan draws polluted air into a container fitted with a HEPA filter. The HEPA filter removes particulate matter and harmful pollutants, releasing clean air back into the environment. To enhance environmental monitoring, a DHT11 sensor measures the temperature and humidity of the surroundings. The data from the MQ135 and DHT11 sensors is processed by the NodeMCU and displayed locally on an LCD screen. Additionally, the NodeMCU uploads this data to the Blynk cloud platform, enabling users to access real-time information on air quality, temperature, and humidity through a mobile application.This system is designed for energy efficiency and environmental sustainability. The hybrid power generation mechanism ensures uninterrupted operation in various settings, while the use of cloud-based monitoring provides flexibility and ease of use. By combining smart technology with renewable energy, this system offers a practical and scalable solution to combat air pollution and promote sustainable energy practices in urban, industrial, and public spaces.

V. CONCLUSION

Finally, the proposed hybrid-powered air filtration system demonstrates a promising approach to addressing both air quality and energy sustainability challenges. By harnessing renewable energy sources such as solar power and piezoelectric generation, the system operates off-grid, ensuring continuous operation while minimizing environmental impact. The integration of real-time monitoring technologies and cloud-based platforms enhances its functionality, offering a valuable tool for urban, industrial, and public spaces. As a sustainable, eco-friendly, and cost-effective solution, this system not only improves air quality but also supports the global transition toward renewable energy practices. With potential future advancements, this project holds significant promise for broadening its impact and contributing to both environmental health and energy efficiency, paving the way for more sustainable urban living solutions

VI. FUTURE SCOPE

Integration with IoT and AI – Incorporating IoT will enable real-time monitoring and control, while AI-powered data analysis can predict air quality trends and optimize energy consumption. This will enhance efficiency and adaptability, ensuring smarter and more proactive air purification.

Enhanced Power Generation – Adding wind turbines or kinetic energy harvesting will diversify renewable energy sources, ensuring system reliability in various weather conditions. This will help maintain continuous operation even when solar power is insufficient.

Larger-Scale Deployment – Scaling up the system for commercial buildings, factories, and smart city infrastructure will maximize its impact, improving air quality in densely populated and industrial areas. Larger deployments will contribute to public health and environmental sustainability.

Mobile Integration – Developing mobile applications will enhance user interaction by allowing remote monitoring, real-time alerts, and customization of system settings. This will improve accessibility and user convenience, making air purification more adaptable to individual needs.

Energy Storage Enhancements – Advanced energy storage solutions like supercapacitors and high-capacity batteries will improve energy efficiency and extend operational hours, ensuring uninterrupted function even in low-light conditions or during energy demand fluctuations.

Advanced Filtration Technology – Adding UV or ionization filters will enhance air purification by targeting bacteria, viruses, and finer pollutants. This will increase the effectiveness of the system, making it more suitable for health-sensitive environments such as hospitals and schools.

Smart Integration with HVAC Systems – Integrating the purifier with HVAC systems will enable automatic air purification as part of climate control, optimizing energy use and improving indoor air quality without additional operational complexity.

Data Analytics and Reporting – With improved sensors and cloud-based data storage, the system can generate detailed reports and historical analyses. This will support urban planning, pollution control measures, and public health initiatives by providing actionable insights.

Carbon Footprint Reduction – Using renewable energy sources and reducing reliance on conventional power will decrease carbon emissions, aligning the system with global sustainability goals. This will support greener urban and industrial environments.

Global Deployment – Enhancing cost efficiency and portability will make the system viable for deployment in pollution-heavy regions, particularly in developing countries where air quality monitoring is limited. This will have a significant global environmental and health impact.

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