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Design And Development Of Automated Air Pollution Detection And Response System Using Iot Technology

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Abstract: The Air pollution has become one of the most critical envirommental concern increasing industrialisation,vehicle emission and indoor pollutants. Which Directly impacts to human health,the ecosystem, and the climate. To address this, an Advanced Pollution Control and Monitoring System is proposed. It integrates smart sensing, automatic control, and lot based data communication. The system employs a combination of gas sensors (for CO2,NH3,NO), particulate matter sensors and environmental sensors (temperature, humidity,) to provide real-ime measurement of air quality parameters.A microcontroller unit (ESP32/Raspberry Pi) processes the sensor data, calculates the Air Quality Index and applies intelligent decision-making algorithms. When pollutant levels exceed safe thresholds, the system automatically activates actuators such as exhaust fans, air purifiers, or industrial filters through relay control, thereby reducing local pollution levels. By integrating loT connectivity, and automatic pollution control, this project offers a scalable solution for smart homes, industries, and smart city applications, contributing to sustainable environmental management.

IndexTerms- Industrialisation,Environmental concern, Monitoring system,Actuators,Air quality index,Environmental sensors, Smart city Application,Sustainable Environment

I. INTRODUCTION

Air pollution is one of the most serious environmental problems affecting human health and the ecosystem. It occurs when harmful substances such as gases, dust particles, smoke, and biological molecules are released into the atmosphere in quantities that are harmful to living organisms and the environment. Rapid industrialization, urbanization, and the increasing number of vehicles have significantly contributed to the deterioration of air quality across the world [1] . Several studies have shown that exposure to air pollution at an early age can impair lung function, and increase the risk of respiratory diseases as well as the probability of premature mortality[2].

Air pollutants can be categorized into primary and secondary pollutants. Primary pollutants are directly emitted from sources such as factories, vehicles, and burning of fossil fuels[3]. Examples include carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen oxides (NOx), and particulate matter (PM). Secondary pollutants are formed when primary pollutants react with other components in the atmosphere. Ground-level ozone is a common example of a secondary pollutant.Poor air quality can lead to severe health issues including respiratory diseases, heart problems, asthma, and lung cancer. According to global health reports, millions of people die every year due to air pollution-related diseases. In addition to human health, air pollution also affects plants, animals, buildings, and the overall climate system.

With the growth of smart technologies and the Internet of Things (IoT), it has become possible to monitor environmental conditions in real time[4]. Smart air pollution monitoring systems use sensors and microcontrollers to detect pollutants and provide data that can be analyzed for better environmental management[5].

A smart air pollution monitoring system provides a more efficient solution by using sensors, microcontrollers, and IoT technology to continuously measure air quality parameters[6]. These systems can detect harmful gases and particulate matter and transmit the data to a cloud platform for analysis and visualization. For instance, air pollution monitoring in a smart city helps to improve health in citizens when alerts are created if the contamination overpasses a specific threshold [7]. Real-time monitoring enables authorities and individuals to take immediate actions to reduce pollution exposure[8]. For example, alerts can be generated when pollution levels exceed safe limits, allowing people to take precautions such as wearing masks or avoiding outdoor activities. Smart monitoring systems are also cost-effective, portable, and scalable. They can be deployed in multiple locations, including residential areas, industrial zones, and traffic intersections, to create a comprehensive pollution monitoring network[9].

In the future, the system can be enhanced by integrating advanced technologies such as artificial intelligence, machine learning, and predictive analytics to forecast pollution levels[10]. It can also be integrated with smart city infrastructure to improve environmental monitoring and management.

II. LITERATURE SURVEY

In recent years, research in this field has gained significant attention due to its growing importance and wide range of applications. A number of studies have been conducted by various researchers to explore different aspects of the air pollution,providing valuable insights and contributing to the development of knowledge. This section presents a review of the existing literature, highlighting key findings, methodologies, and gaps in previous work, which form the basis for the current research. Conventional air pollution monitoring systems rely on large and complex monitoring stations installed by government agencies. These stations use high-precision instruments to measure different pollutants such as particulate matter, carbon monoxide, ozone, and sulfur dioxide.Although these systems provide accurate measurements, they have several disadvantages.

Existing system limitations

- High installation and maintenance cost
- Limited geographical coverage
- Lack of real-time monitoring in small areas
- Complex infrastructure requirements

Due to these limitations, only a few monitoring stations are installed in major cities, which makes it difficult to measure air pollution levels across all regions. This limitation has motivated researchers to develop portable and low-cost monitoring systems using embedded technologies.

Proposed system

The literature survey shows that IoT-based air pollution monitoring systems are gaining popularity due to their low cost, portability, and real-time monitoring capabilities. These systems integrate sensors, microcontrollers, wireless communication, and cloud platforms to monitor environmental conditions effectively.

Researchers have demonstrated that smart monitoring systems can significantly improve air quality monitoring and provide valuable data for environmental management. However, further improvements are required in sensor accuracy, network reliability, and large-scale deployment. Researchers have also explored different system architectures for implementing smart pollution control. Most systems follow a layered approach that includes sensing, processing, communication, and application layers. Microcontrollers such as Arduino and Raspberry Pi are commonly used to process sensor data, while communication technologies like Wi-Fi, GSM, and LoRa enable data transmission. Cloud computing platforms are used to store and process large volumes of data, making the system scalable and efficient.

The proposed Smart Air Pollution Monitoring and Control Unit aims to address these challenges by developing a cost-effective system capable of detecting air pollutants and providing real-time monitoring and alerts. These systems typically consist of gas sensors, microcontrollers, and communication modules that collect data on pollutants such as carbon monoxide, carbon dioxide, Ammonoia,nitrogen, and particulate matter. The collected data is transmitted to cloud platforms where it can be analyzed and visualized through web or mobile applications. This approach allows authorities and users to monitor air quality remotely and receive instant alerts when pollution levels exceed safe limits.

In addition to monitoring, recent studies have incorporated machine learning and artificial intelligence techniques to enhance the functionality of pollution control systems. These technologies are used to analyze historical data, predict future pollution levels, and identify patterns in environmental changes. Predictive models such as regression algorithms and time-series forecasting methods help in taking preventive actions before pollution reaches hazardous levels. This shift from reactive monitoring to proactive control is considered a major advancement in smart environmental systems.

0bjectives of the project

- To design and develop a smart system capable of detecting harmful gases and pollutants in the air.
- To monitor environmental parameters such as temperature, humidity, and particulate matter using sensors.
- To display real-time air quality data on a display unit or IoT platform.
- To alert users when pollution levels exceed safe limits.
- To develop a cost-effective and portable pollution monitoring solution.

Furthermore, smart pollution control systems play a significant role in smart city development. Studies show that integrating these systems into urban infrastructure can help in better traffic management, industrial regulation, and public health monitoring. Some research also proposes mobile monitoring units that can be installed on vehicles to collect pollution data from different locations, providing a more comprehensive analysis of environmental conditions.

III. BLOCK DIAGRAM

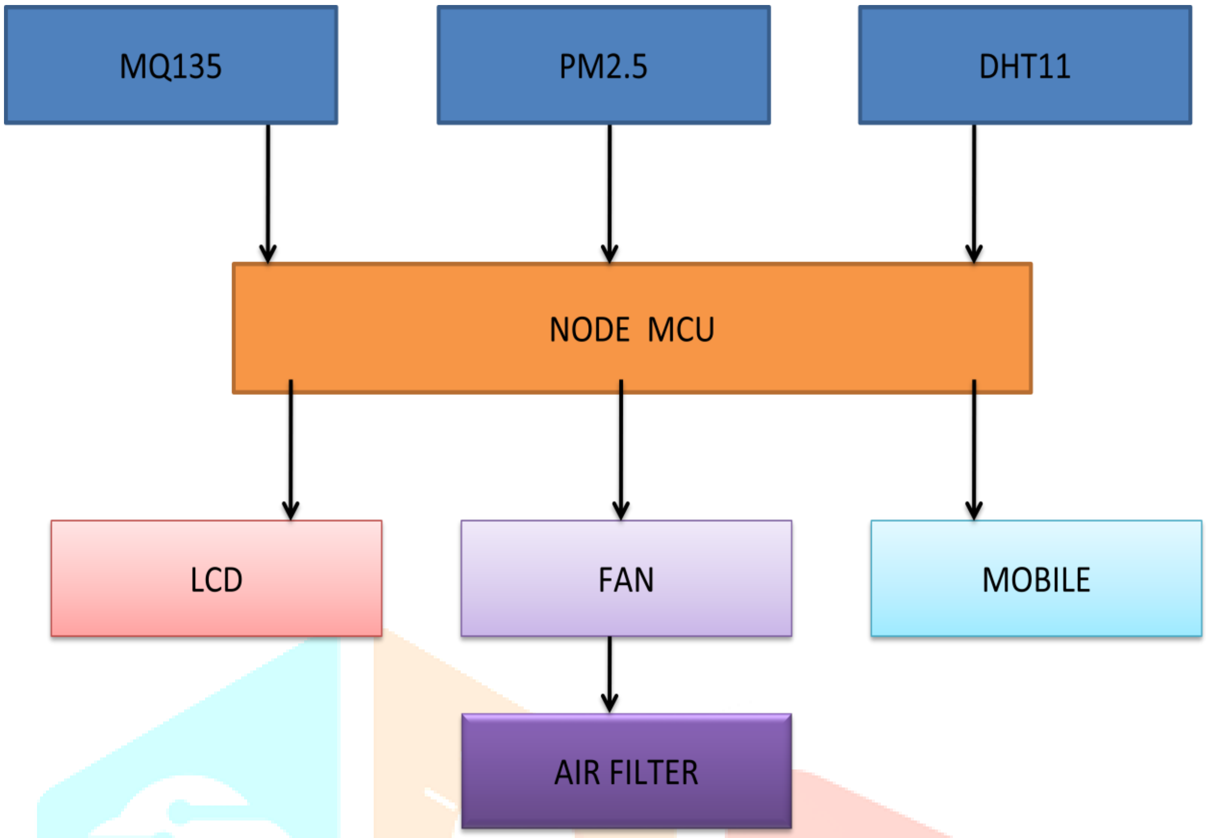

Fig-1:block diagram

3.1 MQ135

The MQ-135 is a widely used sensor designed to detect harmful gases in the air, such as ammonia, carbon dioxide, benzene, and smoke. It operates based on changes in resistance when exposed to different gas concentrations. This sensor is commonly applied in air quality monitoring systems to evaluate pollution levels. It provides both analog and digital outputs, making it compatible with various microcontrollers. Due to its sensitivity and affordability, it is often chosen for environmental and safety-related projects

3.2 PM 2.5

The PM2.5 dust sensor is used to detect very small airborne particles such as dust, smoke, and pollutants present in the air. These particles are harmful to human health and can cause respiratory problems. The sensor works Uses the idea of light scattering, where an infrared LED emits light inside the sensor chamber. When dust particles go through the chamber, the light bounces off them and is picked up by a photodiode. The sensor transforms this scattered light intensity into an electrical signal which indicates the dust concentration. The NodeMCU reads this signal and calculates the PM2.5 value in micrograms per cubic meter (µg/m³).

3.3 DHT11

The DHT11 is a basic sensor used to measure temperature and humidity in the surrounding environment. It contains a thermistor for temperature sensing and a capacitive humidity sensor for detecting moisture levels. The device sends calibrated digital signals, which simplifies data reading compared to analog sensors. Although it has moderate accuracy, it is sufficient for general-purpose applications. Its low cost and ease of use make it popular in beginner and intermediate electronics projects.

3.4.NODEMCU

NodeMCU is an open-source development board based on the ESP8266 Wi-Fi module. It allows devices to connect to the internet and exchange data, making it suitable for Internet of Things (IoT) applications. The board includes digital input/output pins, analog input, and built-in Wi-Fi capability. It can be programmed using languages such as Lua or through the Arduino IDE. Its compact size and low power consumption make it ideal for smart automation systems.

3.5 LCD DISPLAY

An LCD is an electronic display module used to show text, numbers, and simple graphics. It works by controlling liquid crystals that block or allow light to pass through, forming visible characters. Common types include 16x2 and 20x4 displays, which indicate rows and columns of characters. LCDs are widely used in embedded systems to provide user feedback and system status. They are energy-efficient and easy to interface with microcontrollers.

3.6 RELAY

A relay is an electrically operated switch used to control high-power devices using a low-power signal. It works by using an electromagnet to open or close contacts in a circuit. Relay modules are often used in automation systems to control appliances like fans, lights, and motors. They provide electrical isolation between the control circuit and the load. This makes them essential for safe operation in many electronic applications.

3.7 EXHAUST FAN

An exhaust fan is used to remove unwanted air, odors, heat, and moisture from an enclosed space. It works by drawing indoor air outside, thereby improving ventilation. These fans are commonly installed in kitchens, bathrooms, and industrial areas. They help maintain a healthier environment by reducing humidity and airborne contaminants. Efficient airflow management also prevents the buildup of harmful gases.

3.8 AIR FILTER

An air filter is a device that removes dust, pollutants, and harmful particles from the air. It improves air quality by trapping contaminants such as smoke, pollen, and microscopic debris. Filters are commonly made from materials like fiberglass, activated carbon, or HEPA layers. They are used in homes, industries, and air purification systems. Regular maintenance or replacement is necessary to ensure effective performance.

IV. RESULTS AND DISCUSSION

4.1 Working of the system

The Smart Pollution Control and Monitoring System works by constantly measuring environmental factors, processing the data using a microcontroller, and taking action to lower pollution levels when needed. The system includes several sensors connected to a NodeMCU microcontroller, including an MQ135 gas sensor, a PM2.5 dust sensor, and a DHT11 temperature and humidity sensor.

The MQ135 sensor detects harmful gases like carbon dioxide, ammonia, and other pollutants in the air. At the same time, the PM2.5 sensor measures the amount of fine dust particles in the air, which is a major contributor to air pollution and can affect respiratory health. The DHT11 sensor checks the temperature and humidity levels, which can impact pollution and air quality.

These sensors regularly gather environmental data and send it as signals to the NodeMCU microcontroller.The microcontroller processes the data and translates it into values that show the current pollution levels. It then compares these values with the set threshold limits in the program.

If the pollution levels are within a safe range, the system shows the sensor readings on an LCD screen and sends the data to the user's mobile device via WiFi using IoT technology. This allows the user to monitor air quality in real time from any location.

However, if the pollution levels go beyond the safe limit, the NodeMCU automatically turns on pollution control devices like a fan and an air filter.The fan helps move air around, while the filter removes harmful particles and pollutants. This automatic system helps reduce pollution and improve air quality.At the same time, the sensor data and system information are sent to a mobile app or IoT platform.

In this way, the system offers a smart and automated solution for real-time pollution monitoring and control, ensuring to maintain healthier and safer air quality in indoor or industrial spaces.

4.2 Results of Descriptive Model

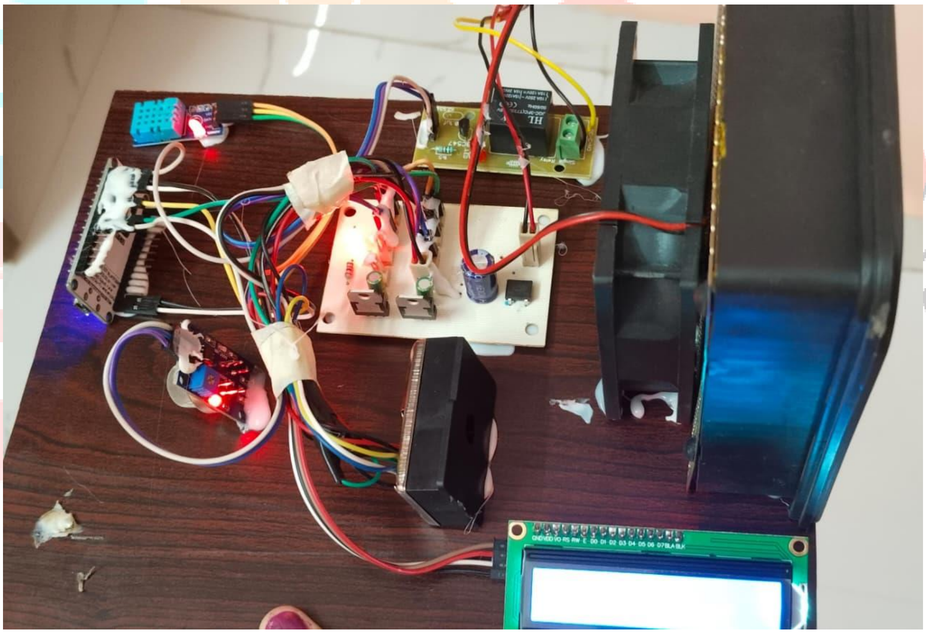

Fig-2:Smart pollution control model Side view

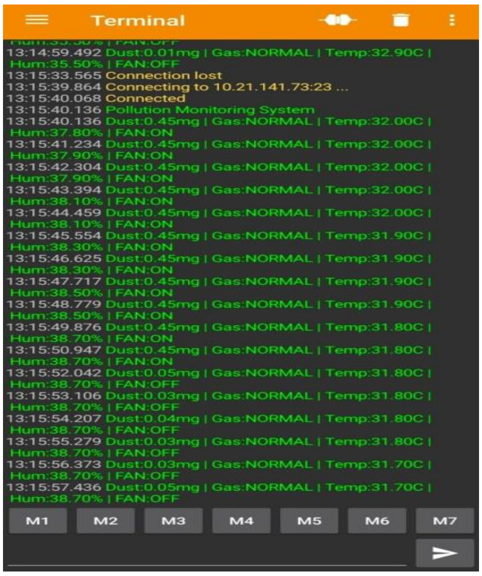

Fig-3: Real Timemonitoring display in mobile Values

Fig-4: LCD Indication

V.CONCLUSION

This project successfully demonstrates an effective system for monitoring and improving air quality using modern electronic components. By integrating sensors like MQ-135 and DHT11 with the NodeMCU, real-time environmental data can be collected and analyzed. The use of an LCD display ensures that the information is easily accessible to users. Additionally, the relay-controlled exhaust fan and air filter help in reducing harmful pollutants automatically. This automation enhances safety and minimizes human effort in maintaining a healthy environment. The system is cost-effective, energy-efficient, and suitable for both domestic and industrial applications. It also highlights the importance of IoT-based solutions in addressing environmental challenges. Overall, the project provides a practical and scalable approach to smart air quality management.

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