UAV And UGV-Based Remote Multi-Gas Sensing for the Petroleum Industry and Environmental Monitoring

Dharmesh Bhatu[1], Yash Chavan[2], Yash Gimonkar[3] , Roshan Mahankuda[4] , Dr. Ulhaskumar Gokhale[5]

[1234]students, Dept. Of Electronics And Telecommunication, Atharva College Of Engineering, Mumbai
[5]Professor, Dept. Of Electronics And Telecommunication, Atharva College Of Engineering, Mumbai

---***---

Abstract - The integration of UAVs (Unmanned Aerial Vehicles) and UGVs (Unmanned Ground Vehicles) for remote multi-gas sensing represents a significant advancement in monitoring applications for the petroleum industry and environmental safety. This project aims to design and implement a system that utilizes UAVs for aerial gas detection and UGVs for ground-based sensing, providing a comprehensive solution for real-time monitoring of hazardous gases such as methane, carbon dioxide, and volatile organic compounds. The proposed system will enhance safety by offering rapid, flexible, and scalable detection in hard-to-reach or high-risk areas. By combining the mobility of UAVs with the precision of UGVs, this technology enables effective, continuous monitoring of oil fields, refineries, and surrounding environments. This dual-platform approach not only improves operational efficiency but also supports environmental sustainability by ensuring early detection of potential hazards, minimizing human exposure, and aiding in timely responses to gas leaks or pollution events.

Key Words: UAV, UGV, Remote sensing, Multi-gas detection, Petroleum industry, Environmental monitoring, Real-time monitoring

1.INTRODUCTION

The petroleum industry and environmental monitoring sectors face increasing challenges in managing air quality and detecting hazardous gases. In industrial environments, the release of toxic gases such as methane, carbon monoxide, and volatile organic compounds (VOCs) poses serious safety risks, while environmental monitoring requires continuous and precise data collection. Traditional gas detection systems often fall short due to limitations in coverage, accessibility, and real-time data acquisition. To address these issues, this project explores an innovative solution that combines the mobility and versatility of Unmanned Aerial Vehicles (UAVs) and Unmanned Ground Vehicles (UGVs), equipped with MQ-9 and MQ-135 gas sensors, to remotely monitor and analyze gas emissions in real-time. By integrating the ESP8266 Wi-Fi module with these gas sensors, this system offers a scalable, cost effective, and efficient approach to environmental and industrial monitoring. The UAVs provide extensive coverage, enabling monitoring of hard-to-reach areas, while UGVs offer detailed analysis in confined spaces. The MQ-9 sensor detects combustible gases like methane and carbon monoxide, while the MQ 135 measures a wide range of air pollutants, including VOCs. Real-time data transmission via the ESP8266 to a cloud platform enables remote monitoring, timely alerts, and rapid response to hazardous conditions. This project aims to enhance safety, optimize environmental management, and provide a forward-thinking solution for air quality monitoring in complex environments.

2. Literature Survey:

The reviewed literature emphasizes the integration of UAVs and UGVs for hazardous gas detection and infrastructure inspection, aiming to reduce human exposure in dangerous environments. The combination of sensor-equipped autonomous systems ensures efficient and accurate monitoring. Additionally, UAVs demonstrate growing relevance in environmental surveillance through high-resolution air quality data collection.

smart autonomous inspection system that merges UAVs and UGVs to detect harmful gases and examine industrial infrastructure. It highlights the use of MQ-135 and MQ-9 sensors mounted on aerial and ground platforms, enabling gas detection at both surface and atmospheric levels. The modular system design includes components for navigation, gas processing, and inspection logic, improving safety and accuracy in hazardous zones. Core functions such as fly(), traverse(), navigate(), and detect() automate the system's operations. The setup significantly reduces the need for human intervention in toxic environments like chemical plants or underground areas. Furthermore, the system proves scalable and versatile, applicable in disaster management and smart industry frameworks. This approach aligns with current trends in industrial automation and environmental safety enhancement.[1]

3. Block Diagram:

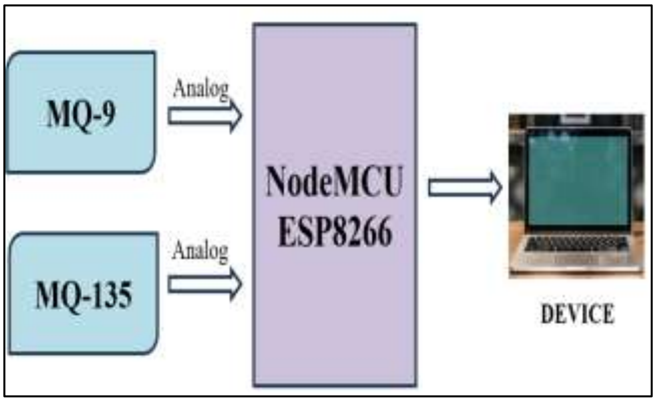

Fig -1: Figure

The block diagram represents a gas detection system utilizing MQ9 and MQ135 sensors, a NodeMCU ESP8266 microcontroller, and an output device. The MQ9 sensor detects gases such as carbon monoxide (CO), methane (CH4), and liquefied petroleum gas (LPG), while the MQ135 sensor identifies air pollutants like ammonia (NH3), sulfur dioxide (SO2), and carbon dioxide (CO2). These sensors send real time data to the NodeMCU ESP8266, which processes the information and transmits it wirelessly. Based on the gas concentration levels, the system triggers the connected device, which could be an alarm, display, or cloud-based monitoring system. This setup is commonly used for air quality monitoring, industrial safety, and smart home automation.

3.1 Sensors Used:

- **MQ-9**: Detects gases like CO and CH_4.
- **MQ-135**: Detects harmful gases like NH_3, NOx, alcohol, benzene, smoke, and CO_2.

3.2 Signal Type:

- Both sensors provide analog outputs proportional to the concentration of gases detected.

3.3 Microcontroller:

- **NodeMCU ESP8266** receives the analog signals.
- It processes and converts the sensor data for further use.
- It features built-in Wi-Fi, enabling wireless communication.

3.4 Data Transmission:

- The processed data is sent wirelessly from the NodeMCU to a DEVICE (laptop or other display system).

3.5 Output Device:

- The device (shown as a laptop in the diagram) receives the data for monitoring and visualization.
- It can display real-time gas levels and alert users if harmful levels are detected.

4. System Design

The system design for this project focuses on the integration of UAVs (Unmanned Aerial Vehicles) and UGVs (Unmanned Ground Vehicles) equipped with multi-gas sensors to detect hazardous gases in the petroleum industry and for environmental monitoring. The system is designed to provide real-time data from both aerial and ground-based platforms. Below is the detailed description of both hardware and software components used in this system.

4.1 Hardware design:

MQ-9 Gas Sensor (Methane and LPG detection):

This sensor is used to detect methane and other harmful gases that are common in the petroleum industry. It has a wide detection range and is sensitive to low concentrations of gases.

Function : This sensor detects methane and LPG gases commonly found in the petroleum industry. It provides an analog output based on the concentration of gases it senses in the environment.

MQ-135 Gas Sensor (Air Quality and VOCs detection):

This sensor is used for detecting hazardous gases such as carbon dioxide, ammonia, and benzene. It is especially useful for monitoring environmental air quality.

Function: The MQ-135 sensor is used for detecting a range of gases such as carbon dioxide, ammonia, and VOCs (Volatile Organic Compounds). It also generates an analog signal corresponding to the detected gas concentrations.

NodeMCU ESP8266:

The NodeMCU ESP8266 module serves as the microcontroller to read data from the sensors. It also manages communication with a central data collection device via Wi-Fi for real-time monitoring. This module has Wi-Fi capabilities, making it ideal for wireless communication.

Function: Analog-to-Digital Conversion: The analog signals from the MQ-9 and MQ-135 sensors are read by the NodeMCU ESP8266 microcontroller. The NodeMCU converts the analog signals into digital data using its built-in ADC (Analog-to-Digital Converter). Wireless Communication: NodeMCU ESP8266 has Wi-Fi capabilities. It transmits the gas concentration data to a central device (e.g., computer, server, or cloud) over the internet for monitoring and analysis.

4.2 Software design :

The various software technologies used to build the device are:-

a) Arduino IDE: The software for this project is developed using the Arduino IDE, which is used to program the NodeMCU ESP8266 microcontroller. The IDE provides an easy-to-use interface for writing and uploading code to the microcontroller. The Arduino IDE is ideal for handling sensor data collection, communication, and processing.

b) Code Workflow:

Sensor Initialization: The sensors (MQ-9 and MQ-135) are initialized in the setup function of the code. They begin sampling environmental data to detect the concentrations of gases.

Data Collection and Transmission: In the main loop, the NodeMCU reads data from the sensors continuously. This data is then formatted and sent to the data collection device using Wi-Fi communication (over HTTP or MQTT protocols).

Real-time Monitoring: The data collection device receives the sensor data and displays it on a user interface, allowing for real-time monitoring of the gas levels in the petroleum site or surrounding environment.

5. CONCLUSIONS

The UAV and UGV-based remote multi-gas sensing system presents a significant leap forward in the fields of environmental monitoring and petroleum industry surveillance. By combining cutting-edge gas detection sensors (MQ9 and MQ135), IoT technology (NodeMCU ESP8266), and the mobility of unmanned aerial (UAV) and ground vehicles (UGV), this system provides a unique solution for real-time air quality monitoring over large, often inaccessible, areas. Traditional gas detection systems, often limited by fixed installations or manual monitoring, cannot match the flexibility, scalability, and reach that this system offers. UAVs and UGVs can be deployed across a wide range of environments, including hazardous or hard-to-reach locations like petroleum fields, offshore oil rigs, and industrial zones. This ensures that gas concentrations are monitored continuously without the need for human intervention. One of the key advantages of this system is its ability to transmit data wirelessly in real time to cloud platforms like ThingSpeak or Blynk using the NodeMCU ESP8266. This connectivity allows for remote monitoring and immediate alert notifications when dangerous gas levels are detected. In turn, this facilitates quick decision-making and helps prevent potential accidents. The data is processed and displayed in a clear and accessible format on cloud-based dashboards, which users can access anytime, anywhere, ensuring enhanced safety and operational efficiency. In addition to its real-time capabilities, the system is highly cost-effective. The use of low-cost components such as MQ sensors and NodeMCU significantly reduces both the initial setup cost and maintenance expenses, making it an affordable solution for industries seeking reliable and scalable gas monitoring. Its automation ensures constant surveillance without human error or labor costs, further improving operational efficiency. By integrating mobility, real-time data transmission, and cloud-based analytics, this system marks a major step toward safer, more efficient gas detection for the petroleum industry and environmental monitoring. The UAV and UGV-based system provides a robust, scalable, and cost effective solution for the challenges of modern gas monitoring and environmental protection.

REFERENCES

[1] Nasim Khan, Vishal Jadhav , Sai Jadhav , Sahil Bhosale ,Asst.Prof Sandip Zade (2024), Uav And Ugv-Based Remote Multi-Gas Sensing For The Petroleum Industry And Environmental Monitoring. Volume:11 Issue: 03 Mar 2024, e-ISSN: 2395-0056, p-ISSN: 2395-0072

[2] Pflugmacher,d., et al. (2016). Applications of Unmanned Aerial Vehicles in the forest Industry.Journal of Unmanned Vehicle Systems.

[3] Anderson, K., & Gaston, K. J. (2013). Drones in Ecology: A Review of Progress and Potentials. Frontiers in Ecology and the Environment.

[4] Sankaran, S., et al. (2015). Review of Advances in Small Unmanned Aircraft System (sUAS) Remote Sensing in Mapping and Monitoring of Agricultural Crops and Weeds. The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences.

[5] Shakya, N. M., & Qu, Y. (2018). A Survey of UAV-Based Applications for Precision Agriculture. IEEE Access. Volume: 07,Issue: 09 April 2019, e-ISSN: 2169-3536

[6] Hunt, E. R., et al. (2010). Unmanned Aerial Systems for Remote Estimation of Vegetation Fraction. International Journal of Remote Sensing.

[7] Khodaei, B., et al. (2018). A Review of UAVs Photogrammetry Topographic Modeling Environmental Applications. Geocarto International.

[8] Nex, F., et al. (2019). Monitoring of Water Quality Parameters Using UAVs: A Review. Water.