International Journal of Trend in Scientific Research and Development (IJTSRD)
Volume 9 Issue 5, Sep-Oct 2025 Available Online: www.ijtsrd.com e-ISSN: 2456 – 6470

Remote Monitoring of Natural Gas Pipeline Compressor Stations using ThingSpeak Platform

Kaosoluchukwu Stanislaus Ogbuokebe, Fredrick Alapa, Blessing Baryat Omowumi, Oluwatosin S. Aremo, George Echiye Okpanachi

Center for Satellite Technology Development (CSTD), National Space Research & Development Agency (NASRDA), Obasanjo Space Center, Airport Road, Abuja, Nigeria

ABSTRACT

Compressed Natural Gas (CNG) is mainly comprises of methane and is produced by compressing natural gas to less than 1% of its original volume, making it suitable for transportation and other applications. However, fears arise regarding the natural gas infrastructure such as compressor stations' emissions in the host communities, which can release Volatile Organic Compounds (VOCs), Nitrogen Oxides (NOx), and other pollutants that can affect human health negatively and lead to ozone formation, especially for nearby communities. This research aims to monitor the presence of methane gas in the atmosphere with concentration measuring in Parts Per Million (ppm). The proposed system collects data from methane gas sensor MQ-4. Data collected from this sensor are uploaded to the server via ESP-32 Wi-Fi module. By employing ThingSpeak server, an open-source Internet of Things (IoT) platform, data can be monitored by the appropriate authority at any time with the aid of internet browser. ThingSpeak generates a unique channel identity, which could be used in ThingShow App so that user can monitor and visualize the concentration of methane gas when required through mobile devices. This research therefore not only proof the remote and real-time data access but also provides a broader applications of atmospheric monitoring in environmental protection and scientific research.

KEYWORDS: *ESP32 Wi-Fi, Internet of Things, Bluetooth, Monitoring, Wireless Transmission, Atmospheric, Compressed Natural Gas, Methane.*

How to cite this paper: Kaosoluchukwu Stanislaus Ogbuokebe | Fredrick Alapa | Blessing Baryat Omowumi | Oluwatosin S. Aremo | George Echiye Okpanachi "Remote Monitoring of Natural Gas Pipeline Compressor Stations using ThingSpeak Platform" Published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Volume-9 | Issue-5, October 2025, pp.100-104, URL: www.ijtsrd.com/papers/ijtsrd97164.pdf

IJTSRD97424

1. INTRODUCTION

A healthy environment is very influential on the physical health of living things. An important factor supporting a healthy environment is air quality that meets health standards. Air contains oxygen needed for life. Apart from oxygen, there are other substances in the air such as carbon monoxide, carbon dioxide, formaldehyde, fungi, viruses, bacteria, dust and so on. Within certain limits, the levels of these substances can still be neutralized but if it exceeds normal limits it can interfere with health. The World Health Organization (WHO) states that hazardous substances originating from combustion or heating processes can trigger health problems (Kristiyana & Rinaldi, 2020).

Nowadays, CNG has been used as an alternate fuel in automobiles because of rising prices of petrol and diesel (Swetha & Shwetha, 2021). In addition, CNG is a comparatively clean-burning fuel, which produces significantly reduced amount of harmful pollutants such as carbon monoxide and particulate matter compared to petrol and diesel, resulting to improved air quality and lower levels of cardiovascular and respiratory health problems for the public. However, the fear of natural gas infrastructure such as compressor stations' emissions arises, which can release Volatile Organic Compounds (VOCs), Nitrogen Oxides (NOx), and other pollutants that can affect human health negatively and lead to ozone formation, especially for nearby communities (Nagahage et al., 2021). In other to provide adequate environmental and health protection to the natural gas infrastructure host communities, effective air quality monitoring system is essential. In this research, a monitoring system that is capable of detecting the concentration of methane in the atmosphere was developed. This system employs IoT technology using ThingSpeak application integrated (Gubbi et al., 2012) with ESP32 Wi-Fi module and MQ-4 gas sensor as an air quality detector. The value of the methane concentration read by the gas sensor and processed by the Wi-Fi module is sent wirelessly to the IoT ThingSpeak platform which then records logging data in graphical form (Vinu et al., 2019). With this developed system, the appropriate authority can conveniently and effectively monitor the air pollution of the natural gas infrastructure host communities remotely via Wi-Fi module and internet (Gubbi, et al. 2012).

2. Research Methods

2.1. System Architecture

Figure 1 shows the block diagram of the developed system. MQ4 sensor (Figure 2) was used for detecting methane (CH_4) gas concentration. ESP-32 Wi-Fi module was used for wireless data communication between gas sensor and ThingSpeak server (Swetha & Shwetha, 2021).

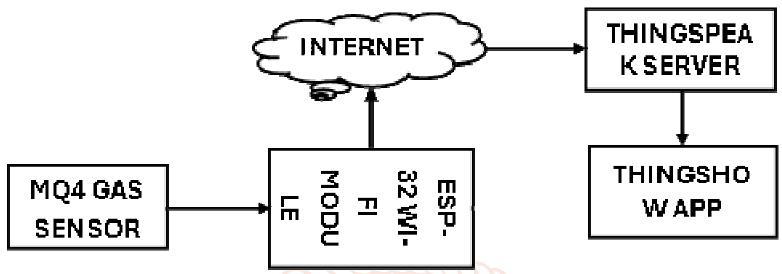

Figure 1: Block Diagram showing the Interfacing of ESP-32 Wi-Fi Module to MQ4 Gas Sensor

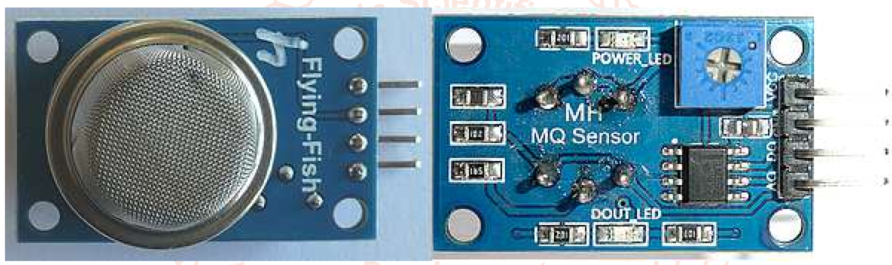

Figure 2: MQ4 Sensor Body Structure

2.2. Wi-Fi Module Programming

An ESP32, a low cost Wi-Fi module was interfaced to MQ-4 sensor. The analog output pin of the MQ-4 gas sensor was connected to the analog input pin of ESP32. Figure 3 shows the picture of the hardware component of the designed system. ESP-32 is the IoT device used in this work, which serves as the central processing unit. Therefore, in order to measure the methane gas concentration and deploy to ThingSpeak server, there is need to upload the required code onto the ESP-32 module. An Integrated Development Environment (IDE) was employed to write the code while Arduino IDE was chosen due to its cross-platform ability, which allows it to upload and execute scripts on a wide range of microcontrollers. In addition, it has a User-Friendly Graphical User Interface (GUI), which is very easy to understand, learn, and utilize (Palkar et al., 2025). The Flowchart of the software program running in the ESP32 is illustrated in Figure 4.

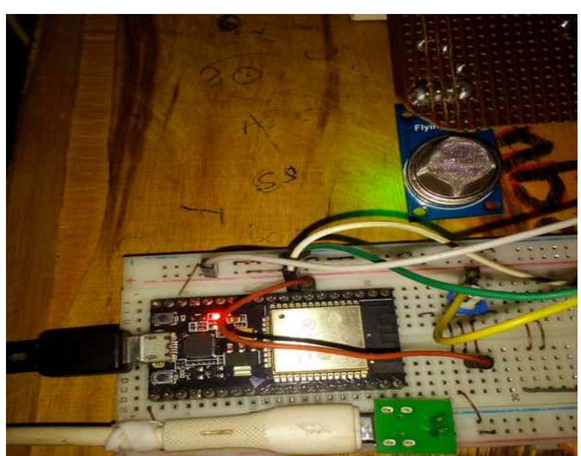

Figure 3: Hardware Implementation with ESP-32 and MQ4 Sensor

2.3. Web Platform Interfacing with IoT Device

The system developed in this research is capable of connecting to ThingSpeak web server through ESP-32 Wi-Fi module, irrespective of the brand of smartphone or operating system being used (Palkar et al., 2025). Different sensors, IoT devices, and websites can wirelessly send data to the ThingSpeak cloud, where it is stored and visualize as either private or public channel. Though, ThingSpeak stores data in private channels by default. However, public channel can be used to share data with other authorized users. The ThingSpeak library, which is an open-source library was used to connect the ESP-32 Wi-Fi module to ThingSpeak cloud (Prananda et al., 2021). The library allows users to simply publish sensor values to single or many fields on the web application. Figure 4 shows the Flowchart for ESP-32 module and web App communication. After, defining the sensor pin and initialize the library, the Arduino code is uploaded to the Wi-Fi module. When powered and reset, the system automatically connects to any available Wi-Fi signal and then checks to read its ADC analog input for available data (Dadafshar 2014). Once the data is available, the ESP-32 processes the sensor data and automatically sends this data to the ThingSpeak web server which in turn connected to the web App.

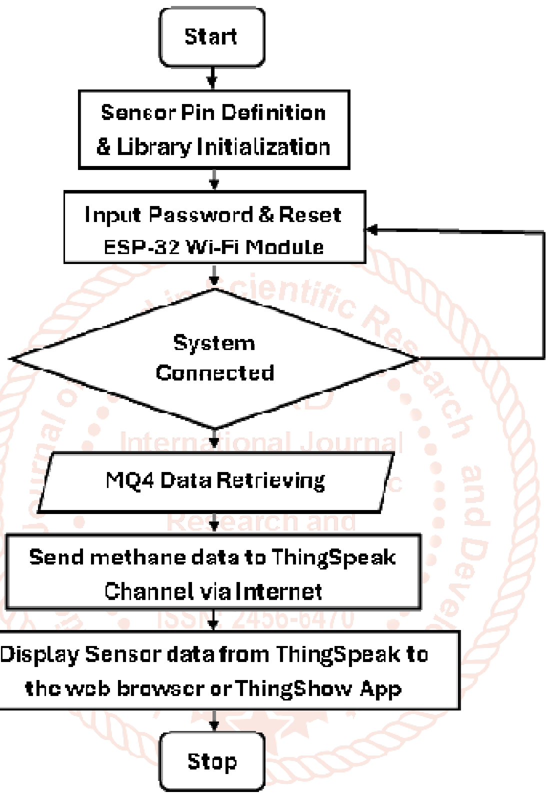

Figure 4: Flowchart for ESP-32 Wi-Fi Module Web App Communication

2.4. System Design

As mentioned earlier, the programing language employed for the ESP32 Wi-Fi module was written using Arduino IDE. The raw data from MQ-4 sensor was stored in the ThingSpeak platform. ThingSpeak was used to collect and analyze data using MATLAB analytics. MQ4 sensor has a built in variable resistor, which varies with the concentration of gas. The sensor resistance R_S decreases with increasing concentration and vice versa. Also, there is need for a load resistor R_L, which serves to adjust the sensor's sensitivity and accuracy. According to the manufacturer's datasheet, the load resistor's R_L value can range from 2kΩ to 47kΩ. The higher the value of this load resistor, the higher the sensitivity of the sensor. Finally, there is also a built-in resistor meant for the heater of the sensor (Jaycon 2025). The heater available inside this sensor is used to give the sensor the temperature requires to make it work properly (Jaycon 2025). MQ4 sensitivity characteristics provide the concentration of a gas in part per million (ppm) with respect to the resistance ratio of the sensor (R_S/R_0). *Rs* is the resistance of the sensor in the presence of gas, and R0 is the resistance of the sensor at known concentration in the absence of gas (in fresh air) (Jaycon 2025). Therefore, sensor resistance *Rs* is calculated from Ohm's Law as ((Nagahage et al., 2021):

$$R_S - [(V_C \; x \; R_L)/V_{RL}] - R_L \; (1)$$

Where V_{RL} is the voltage across the load resistor R_L, V_C is applied voltage.

From the MQ4 sensitivity characteristics graph obtained from datasheet, the ratio R_S/R_0 is 4.4 ppm for methane gas.

To calculate R_0 there is need to calculate the value of the R_S in fresh air. This can be achieved by acquiring the analog average readings (known as ADC_Raw_Value in this work) from the MQ4 sensor and then converting it to voltage (sensor Volt) as:

$$ADC\_Raw\_Value = analogRead(A0) \quad (2)$$

Where A0 is the analog pin on the ESP32 Wi-Fi module.

$$sensorVolt = ADC\_Raw\_Value \; x \; (3.3/4095) \quad (3)$$

Where (3.3/4095) is the standard formula for converting ESP32's Analog-Digital-Converter (ADC) raw reading to actual voltage, where ESP32 has 12-bit ADC. This means that it converts an input voltage between 0V and 3.3 into a corresponding digital value from 0 to 4095.

The methane concentration in ppm was calculated using the following mathematical relationships (MQ-4 technical data) as follows (Nagahage et al., 2021):

$$Methane\ (CH_4)\ Concentration\ in\ ppm = 10^{\left\{\left[\left(\log_{10}\frac{R_S}{R_0}\right)-b\right]/m\right\}} \quad (4)$$

Where *b* and *m* are the intercept and slope of the MQ4 sensitivity characteristics graph respectively.

3. Results

As discussed earlier, ThingSpeak server is an open-source IoT analytics platform, which allows users to store, visualize, and analyze real-time data. Engineers and scientists use ThingSpeak cloud for prototyping and building IoT systems without the need to setup servers or developing web software (Vinu et al., 2019).

The interface of ThingSpeak as the remote monitoring website is shown in Figure 6, which illustrates the concentration of Methane gas obtained from the remote monitoring system developed to monitor the air pollution of the natural gas infrastructure host communities via Wi-Fi module. The amount of gas present in the environment is detected by MQ4 sensor as the methane gas concentration with respect to time. The amount of methane gas measured depends on the distance of the sensor from gas source. This graph has *x-axis*, which represents the time each data arrived, while the *y-axis* represents the concentration of methane gas in ppm as shown in Figure 6.

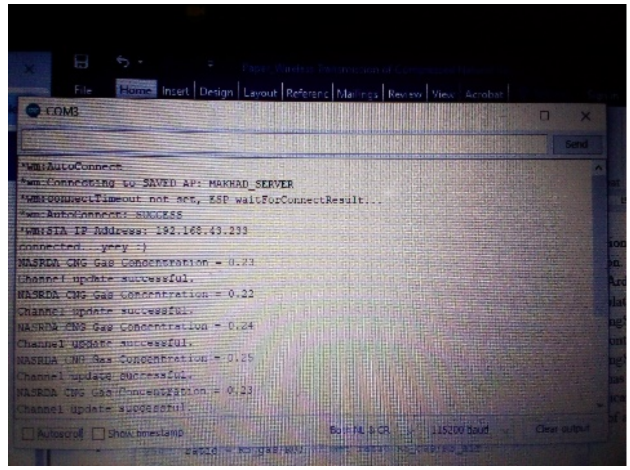

Figure 5: Arduino IDE Serial Monitor Output During Air Pollution Monitoring

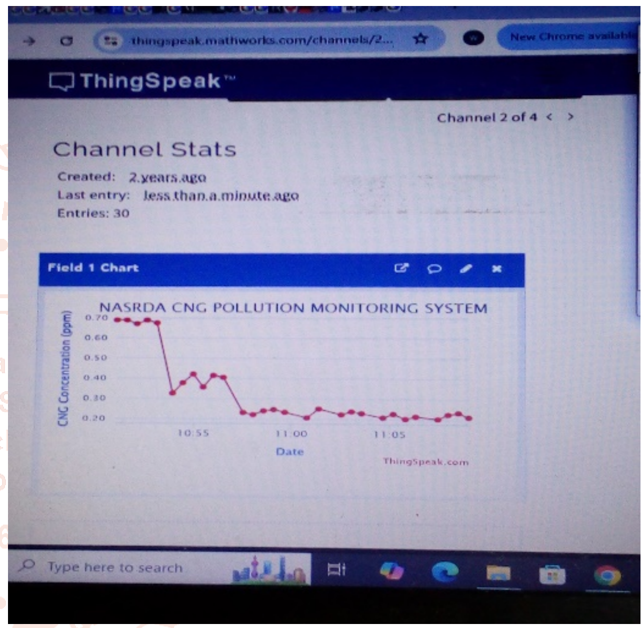

Figure 6: ThingSpeak Output During Air Pollution Monitoring

From Figure 6, it can be seen that the overall performance of the developed system is satisfactory as it is able to detect changes in the concentration of methane gas from 0.21 ppm to 0.25 ppm during outdoor condition. It was however observed that when the system was powered, the system showed higher concentration (0.7 ppm) under room condition (indoor), which could be due to the built-in resistor used for the heater of the sensor. The heater, as described by the manufacturer, is used to provide temperature that the sensor needs to work properly. Therefore, during this initial power up, the sensor has not reached its operating temperature, which is essential for the sensor's sensitivity.

4. Conclusion

As the aim of this research was to develop an Internet of Things-based natural gas compressor stations monitoring system in remote host communities using a Webserver. The system was designed to monitor the concentration of methane gas emissions from remote locations and visualize this data on a webserver. The developed natural gas compressor stations monitoring system accurately measured the concentration of methane gas in the atmosphere. The MQ4 sensor was integrated with the IoT-enabled ESP-32 Wi-Fi module, which has been efficiently used to measure and as well monitor the pollutants in real time. The data are automatically stored in the ThingSpeak database; this information can be used by the appropriate authorities to take prompt actions. In addition, this system is battery powered for portability while user can find out the air quality at any natural gas compressor stations. The Wi-Fi module facilitates the sensor readings and transmission of data through the internet via a dedicated web server which the user can then access remotely from anywhere in the world.

References

[1] Dadafshar, M. (2014). Accelerometer and Gyroscope Sensors: Operation, Sensing, and Applications. Maxim Integrated.

[2] Gubbi, J., Buyya, R., Marusic, S., & Palaniswami, M.S. (2012). Internet of Things (IoT): A vision, architectural elements, and future directions, 29(7), 1645-1660. *ArXiv, abs/1207.0203*.

[3] Jaycon Website, (2025). Understanding a Gas Sensor Available at: https://www.jaycon.com/understanding-a-gas-sensor/

[4] Kristiyana, S., Rinaldi, A. (2020). Air Quality Monitoring System in ThingSpeak-Based Applications Using Internet of Things (IOT), *WSEAS Transactions on Computer Research*, vol. 8, pp. 34-38, DOI:10.37394/232018.2020.8.6

[5] Nagahage, I. S. P., Nagahage, E. A. A. D., & Fujino, T. (2021). Assessment of the applicability of a low-cost sensor–based methane monitoring system for continuous multi-channel sampling. *Environmental Monitoring and Assessment*, *193*(8), 509.

[6] Nagendra Siva Kumar, P., Kamala Kumari, A. (2019). Design of Gas Detection and Monitoring System using IoT, *International Journal of Engineering Research & Technology (IJERT), 8*(11), 463 – 468.

[7] Palkar, M., Deshpande, A., Tavase, S., Potdar, D. (2025). IoT-Enabled Food Spoilage Detection and Waste Reduction System, *International Research Journal of Modernization in Engineering Technology and Science, 07*(06), 2743 – 2748.

[8] Prananda, J., A. A. Masroeri, V. N. Ayukinanthi (2021). Design of Sea Level Monitoring System Using Accelerometer with IoT Based, *International Journal of Marine Engineering Innovation and Research, 6*(3), (2021), 164-174.

[9] Prasad, S. (2010). Design Simulation and Fabrication of Micromachined Acceleration Sensor. Jawaharlal Nehru Technological University.

[10] Sparkfun Website (2025). Technical Data MQ-4 Gas sensor [online available] https://cdn.sparkfun.com/assets/e/f/c/7/d/MQ-4.pdf

[11] Swetha S. V., Shwetha G. N. (2021). LPG/CNG Gas Leakage Detection and Prevention using IoT, *International Research Journal of Engineering and Technology (IRJET), 08*(06), 3035 – 3038.

[12] Vinu A., Abhijith S., Sruthy A.R, Suhail V. V. (2019). Waste Management System with ThingSpeak, *International Research Journal of Engineering and Technology (IRJET), 06*(06), 3869 – 3872.