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IOT-BASED GAS LEAKAGE DETECTION AND CONTROL SYSTEM

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ABSTRACT: Over the years, there have been reported incidences of deaths in the oil and gas industry due to gas explosions. This is due to the delay in the detection of leakages from oil and gas pipelines, especially the flammable gases. This work aims at developing an IoT-based system to detect the presence of methane (a component of natural gas), LPG, CO and temperature levels, to mimic gas leakages in an oil and gas field pipeline; as well as a valve control system to remotely shut off the gas supply in case of detected leakages. MQ2, MQ5 and MQ7 gas sensors were used. The temperature sensor used to detect when there is an explosion is the DS18B20 sensor. Arduino Nano and ESP8266 Microcontrollers were used to process and transmit the received data over the internet, respectively. The system was able to send danger alerts through a buzzer on-site and email to the remote supervisor. It was also able to trigger the shutting of the valve to cut off the supply to the leaking pipe.

Keywords: **Internet of Things, Gas leakage, Control System, Gas sensors, Leakage detection**

I. INTRODUCTION

The operating environment of a typical oil and gas industry is prone to hazards and very unpredictable. These hazards may be due to human or technological activities or some environmental challenges (Horbah et al, 2017). In order to avoid accidents, a focus on safety procedures and the ability to anticipate and detect gas leaks is a critical issue to consider in the oil and gas industry. Sadly though, these aren't the only ways gas leakage threat can occur.

For quite a long time, Oil pipelines have been experiencing three intertwined problems: vandalism, sabotage, and terrorism. The government, pipeline operators, and host communitiesall face significant environmental, economic, health, safety, and security consequences as a result of these issues. Between 2010 and 2012, Nigeria suffered roughly 2,787 pipeline breaks, however between 2002 and 2012, the number was estimated to be over 15,685 (Okoli and Orinya, 2013). Akinpelu (2021) reports that in the 21 months between January 2019 and September 2020, 1,161 pipeline points were vandalized in Nigeria. The highest monthly damages recorded in any of the five axes in the period under review were recorded in 2019, with the highest case being in January 2019 alone with 230 cases of vandalism. This incurred a cost of over 14.9 Billion Naira in repairs and 9.43 Billion Naira in Security. Fig.1 is the picture of a vandalized pipeline that exploded.

Figure 1: Vandalized Pipeline under explosion (Vanguard, 2020)

All these activities in and around the pipelines have been known to lead to environmental pollution of the natural habitat and even explosions; both of which invariably lead to death and economic loss on colossal scales. This threat to the economic strength of the country as well as the health and lives of its citizens, therefore, requires a speedy and efficient solution. One of such solutions would be the development of systems for remote gas leakage monitoring.

Natural Gas is a gaseous substance that exists in Crude Oil and is highly combustible even in its original state. For it to be safely usable, separations need to be carried out to segment it into its many constituents, among which are mainly methane, considerable amounts of the other compounds in the alkane family, water vapour and some very poisonous gases such as Nitrogen and Hydrogen Sulphide. Therefore, a constant leakage of Natural gas into the environment is not ideal; even when combustion has not taken place the gaseous fumes are still capable of causing major air pollution and health failures.

Considering the economic consequences of gas leakage scenarios such as pipeline leakages, which usually occur in remote locations; it is quite necessary to have the means to detect gas leakages, and possible explosions remotely without human involvement. It is alsoparamount that a means of tackling the situation once detected should be made available. Therefore the system proposed in this based valve control operated through relay circuitry.

Since the 19th century, when the first way of detecting the presence of undesired gases in subterranean mines was to use canaries and observe their states, gas sensing mechanisms have been researched. The presence of hazardous fumes is lethal to birds, and the employees would have enough time to flee the scene safely (Barry, 2013). Semiconductors enable the transfer of ions from one medium to another, resulting in a potential difference that can be measured: this is the mechanism utilized in gas sensors (Nasef and Hegazy, 2004). Upon detection, the sensitive layer in contact with the gas impacts the physicochemical interaction leading to the responses via electrical pulses.

Other gases have lately been investigated with the goal of preventing events and catastrophes such as fires and explosions caused by flammable gas leaks, as well as improving the results of industrial processes requiring chemical reactions (Galada et al, 2009). Monitoring and controlling the levels of these gases can improve working conditions, minimize pollution, improve living quality, reduce health problems and death to a minimum, and prevent industrial equipment failure (João et al, 2019).

II. LITERATURE REVIEW

Kodali et al (2018) proposed a gas leakage detector that sends alert to concerned personnel through SMS using IFTTT web service when it detects/senses the presence of harmful gases. This detector senses the presence of harmful gases like liquefied petroleum gas (LPG), Methane and Benzene. The system developed by these authors includes MQ6, MQ4 and MQ135 gas sensors which detect LPG, Methane and Benzene gas leaks respectively and uses ESP-32 as a Wi-Fi module. The concentration levels of the gases are uploaded in the UBIDOTS cloud and the login details are included in the alert message so that the user can have access to the uploaded data if needed. The type of gas leaking is specified by the different colours of LED indicators. Meshram et al (2019) worked on a system that can detect, alert and automatically control gas leaks. The authors used a gas sensor with a high sensitivity to gases such as propane and butane together with LPG. On detecting the leakage of LPG, an alarm is triggered and a personnel is alerted though SMS message.

Some authors worked on systems that not only detect but also control gas leakage. A system for the gas leakage detection and control was developed in (Arpitha et al, 2019). The authors used combustible gas sensor MQ-2 that detects gas concentrations from 200 to 5000ppm for the detection of LPG. The output of the sensor was connected to Raspberry PI 3 model B+. The system was programmed with python. If the sensed data is more than the pre-defined threshold value an alert will be sent to the user and a motor will be activated in order to turn off the gas regulator valve. Yahaya et al (2020) presented an IoT based system for monitoring and controlling Liquefied Petroleum Gas (LPG), which is commonly used as cooking gas at home, in order to prevent leakage. NodeMCU was used as the controller while the data of gas concentration and flame occurrence was processed from MQ-2 sensors and Flame sensors respectively. Blynk application was used as the platform to notify the user when a gas leakage has occurred. It monitors the concentration of gas and controls the fire prevention devices installed along with the system. With this system, the user is able to monitor the concentration of the gas in ppm on their smartphone, receive notifications and remotely take necessary action when gas leakage occurs Mallik et al (2020) developed a system to monitor and control the gas leakage concentration. MQ-6 gas sensor was used for sensing the level of gas concentration in a closed volume. An IoT platform hosted by “Thingspeak” platform was used to monitor the consequences of environmental changes. Robust and cloud-forwarded controls were applied in the system to prevent uncontrolled leakage of gases and auto-ignition. Internet of Things (IoT) techniques was used to design and build a telemetry system to monitor in real-time the concentration of LPG and CO gases in the surrounding air in the work (Flores-Cortez et al, 2021). The authors used central hardware consisting of gas sensors and a microcontroller to monitor gas leakage. Amazon Web Services (AWS) was used as an IoT platform and data storage in the cloud. The main result was a telematics system to monitor in real-time the concentrations of both LPG and CO gases, whose data is accessible from any device with internet access through a website.

III. METHODOLOGY

A. System Hardware Design

The IoT-based gas leakage detection and control system proposed in this work is designed to monitor, detect and control the leakage of flammable Gas and Carbon monoxide in Remote Locations using a Webserver. The system will also monitor the environment for possible explosions using temperature sensor and CO detector. Data transmission is done through the webserver so that the stored information/data can be accessed from any location with internet access. The concerned personnel with authorization can also send control signal to, the user should be able to send a control signal to a relay which conceptually controls a valve to cut off the supply to the pipe from which the gas leakage is coming.

The Sensor for LPG detection is the MQ5 sensor while MQ7 sensor was used for Carbon monoxide detection. The MQ5 reads the intensity of LPG in the atmosphere around the gas leakage site. This data is sent to the microcontroller and after processing, a speedy alert on the presence of LPG leakages is sent to the user. The MQ5 sensor and the DS18B20 sensors come to play in the event of an explosion. The MQ5 sensor can detect the presence of smoke by evaluating the carbon monoxide (CO) content in the atmosphere around it; while the DS18B20 sensor is the temperature sensor. These two sensors detect the two major markers of a fire outbreak-heat (temperature increase) and smoke (composed mainly of carbon monoxide) and therefor the system can alert the user when pre-defined thresholds are exceeded.

The ESP8266 which is an IoT-enabled board that receives sensor data and transmits same over the internet to the storage system. These same contents are made available to the user on a web-enabled device via the webserver to the user. If set threshold is exceeded, a web-based alert (email) is sent to the user informing the user of the danger and urging immediate response. In the event of a gas leakage a control signal is sent to trigger the valves of the said gas pipe to close shutting out supply to it. This would be carried out by a set of relays which will receive the control signal and effect a closing operation. In the case of a fire outbreak, the ESP board will send an alert to have the user shut down the valve and send a response team to the site to stop the fire. The block diagram in fig.2 is an overview of the system.

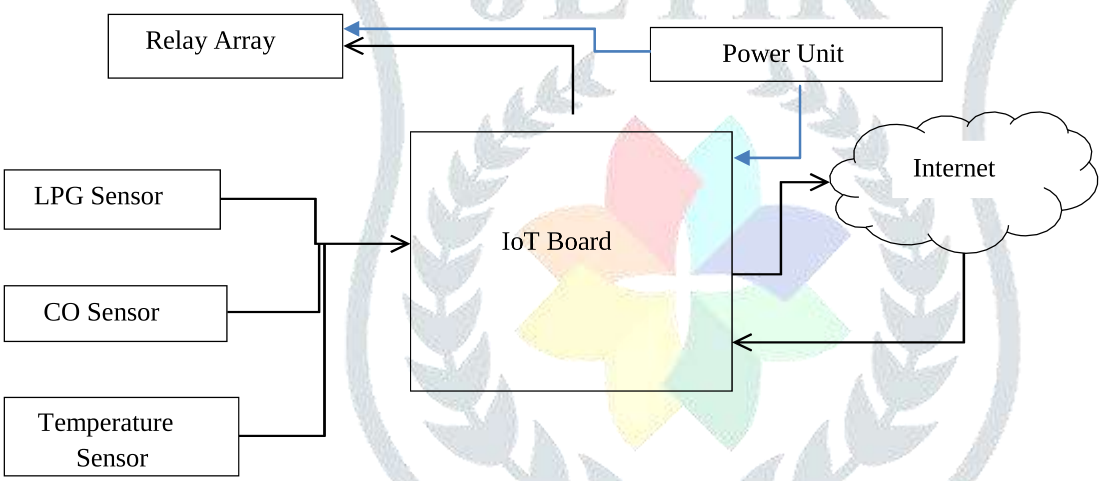

Figure 2: System Block Diagram

Fig.3 is the circuit diagram of the system hardware while fig.4 is the picture of the hardware component of the designed system.

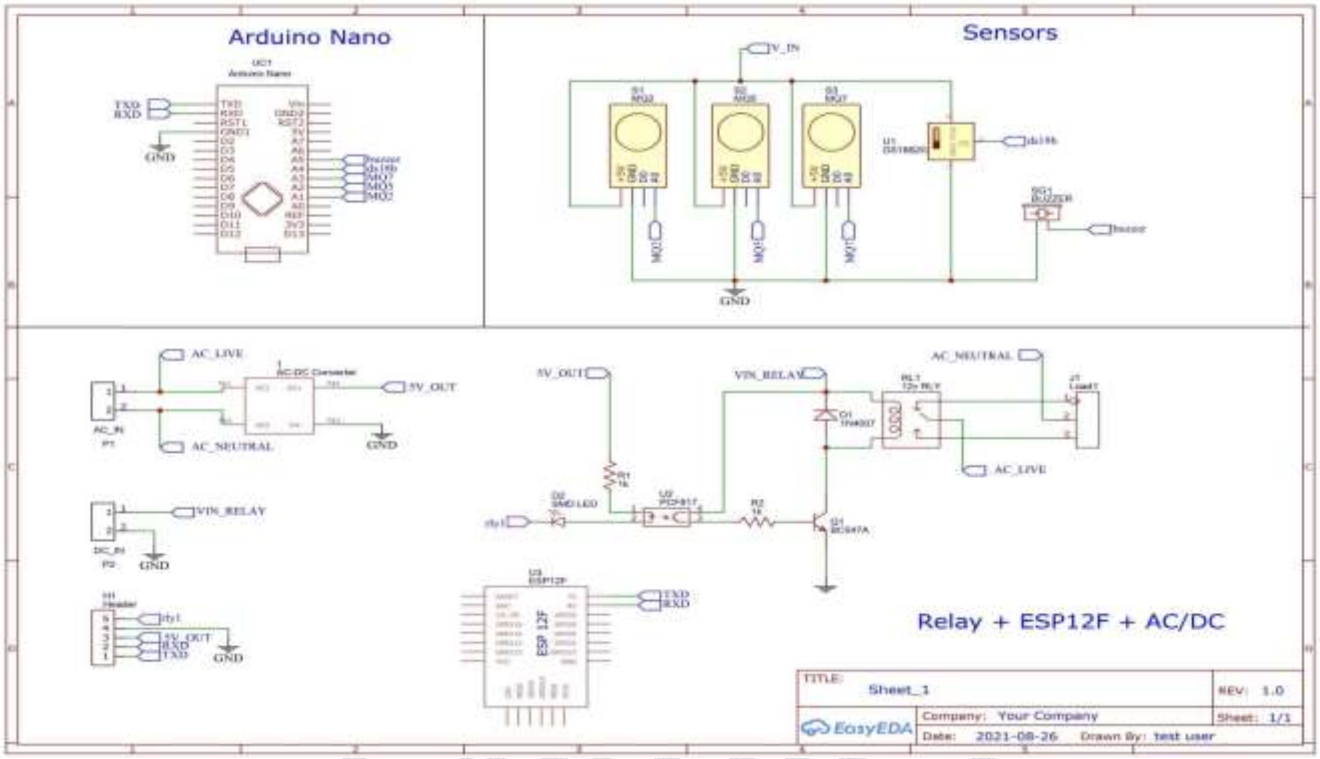

Figure 3: Circuit Diagram of Project design

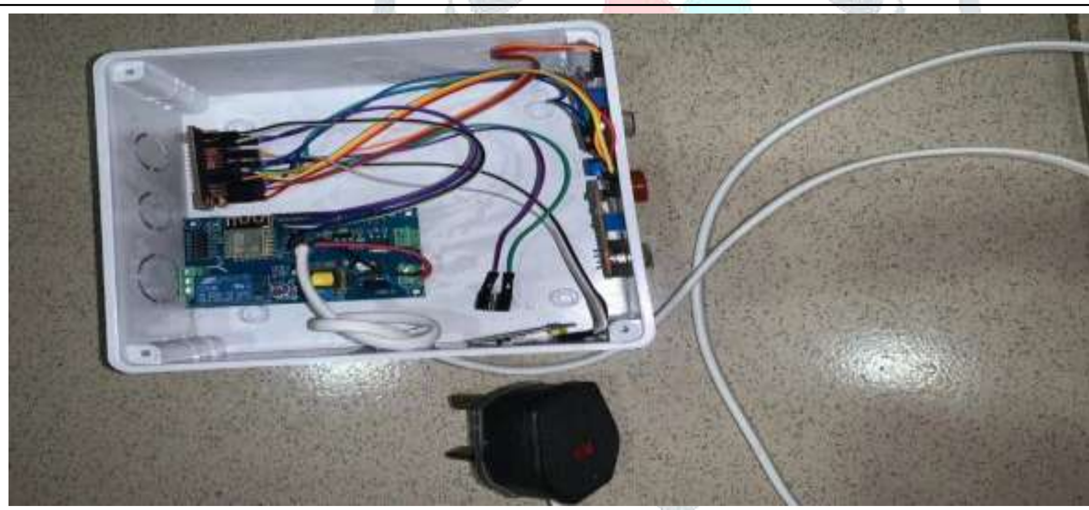

Figure 4: System Hardware

The IoT Board which is the ESP8266 in this case, serves as the central processing unit for all the components combined to form this system. This therefore means that any special programming require for the sensors and relays to run smoothly such as threshold temperature setting, gas concentration threshold, and relay control signal sequence must be programmed into the board.

An Integrated Development Environment is used to write the code that will drive the system's intelligence (IDE). The Arduino IDE was chosen because of its cross-platform interoperability, which allows it to upload and execute scripts on a wide range of microcontrollers, as well as its User-Friendly Graphical User Interface (GUI), which is simple to learn, understand, and use. The Flowchart of the software program running in the Arduino is shown in fig.5.

Upon switching the Arduino Nano into an active state (initialization), all sensors will be powered sequentially. Once all sensors are active, data would begin to stream into the Nano. The Arduino Nano performs two actions at this point: The first action is sending the data received from the sensors straight to the ESP8266 board in a serial communication protocol; the next action is to compare the sensor readings to the set thresholds particular to each sensor. Once any sensor threshold is exceeded, the Nano activates a buzzer to produce a beeping sound indicative of a danger alert and at the same time an email alert is sent to the user. If the threshold is not exceeded, the nano simply keeps reading thesensor data until there is a sign of danger or the system is switched off.

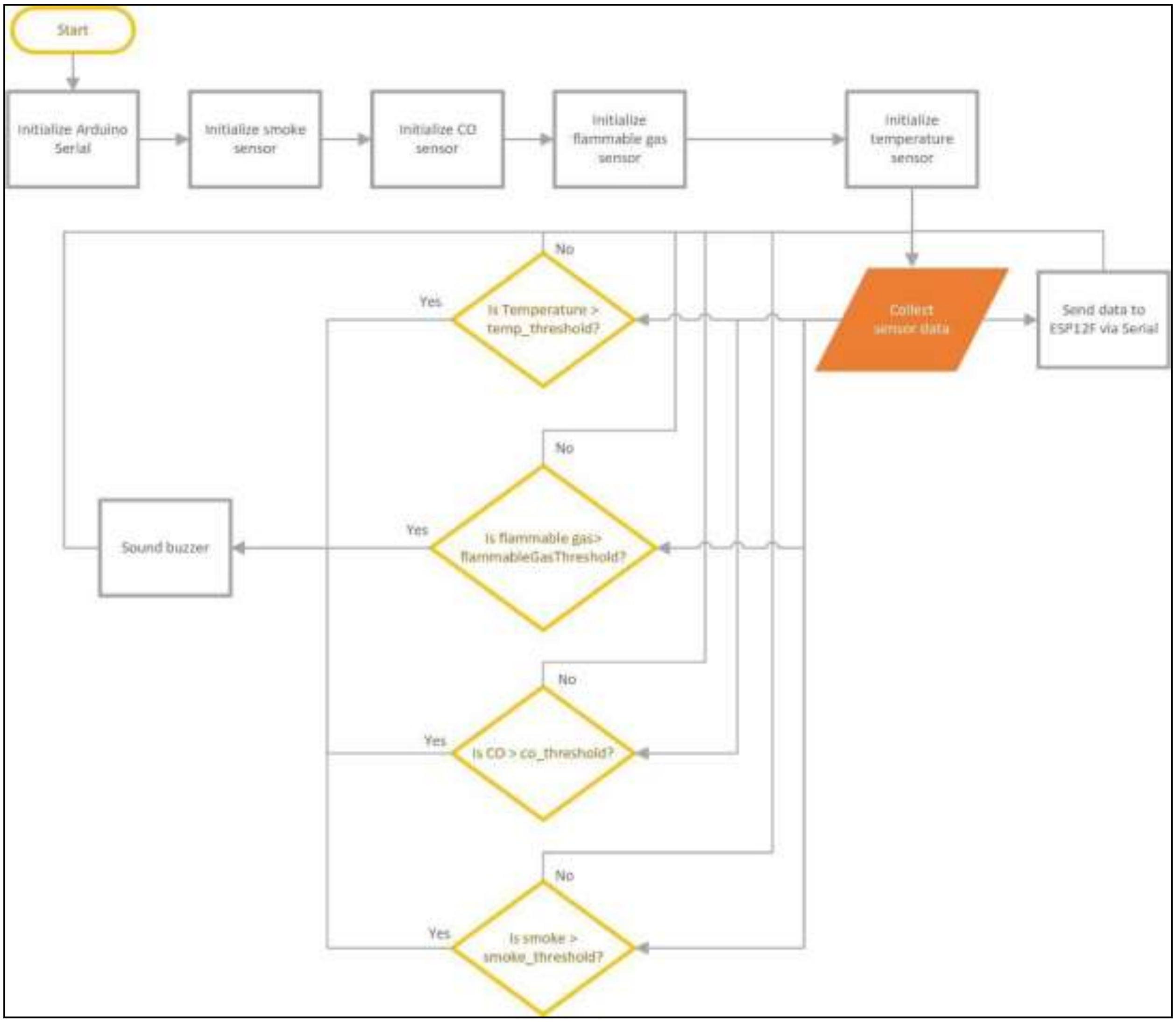

Figure.5: Flowchart for Sensor-Arduino Nano Interfacing

B. Interfacing the web platform with the IoT Board

As has already been implied, the system being designed will be capable of connecting to the web via the IoT Board. This, in essence, means that the system needs to be interfaced with a dedicated web application capable of not only receiving information from the system, but sending back data in form of control signals or feedback. The system is required to utilize a web application because web applications are cross-platform; meaning they can be accessed by users regardlessof the brand of smartphone or operating system they are using. The platform used for the development of the web application used in this work is known as

"ThingSpeak". Sensors, instruments, and websites can transfer data to the cloud, where it is stored in either a private or public channel. By default, ThingSpeak keeps data in private channels however public channels can be used to share information with others. The ThingSpeak-arduino library was used to connect ThingSpeak to the ESP8266 board, which is an open-source library that allows users to simply publish sensor values to single or many fields on the web application. Fig.6 is the Flowchart for ESP – web app communication. The ESP is initialized and automatically connects to an available Wi-Fi signal; after which the code directs the ESP to read its serial inputs for available data. This data is what is sent by the Arduino Nano. Once the data is seen by the ESP, it automatically parses and then sends this data to its web server which is in turn connected to the web app.

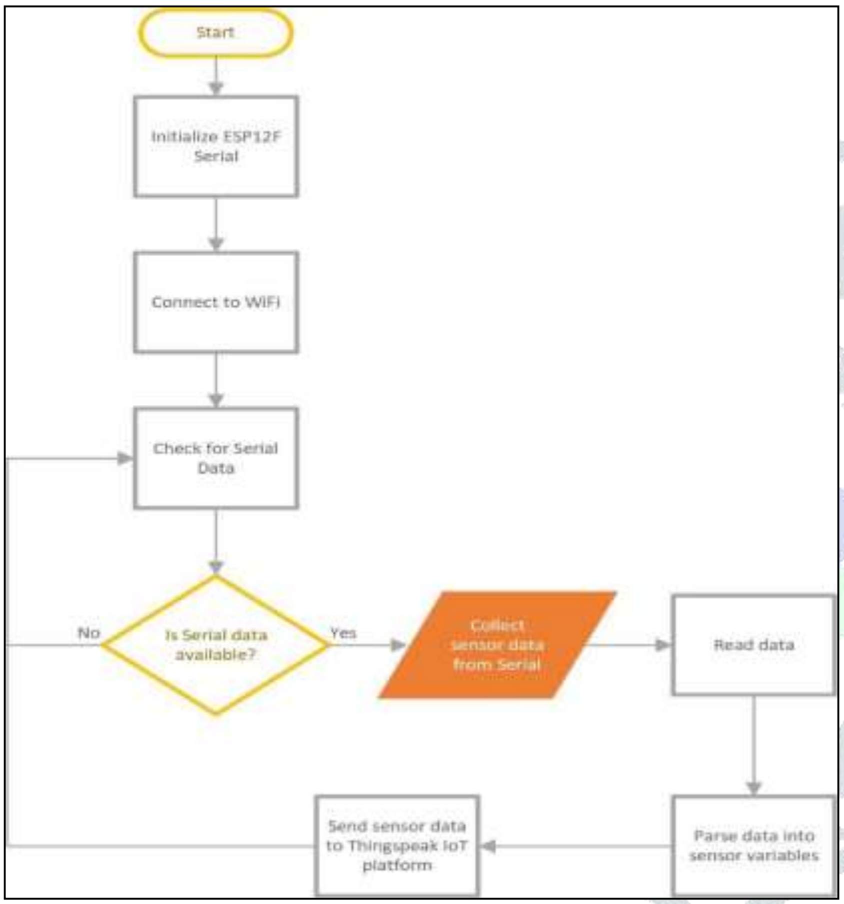

Figure 6: Flowchart for ESP – web app communication

IV. RESULTS AND DISCUSSION

The ESP8266 being guided by the IEEE 802.11 standard of telecommunication offers Wi-Fi capabilities for web server hosting. This in essence means that the IoT board can connect to the website without the use of an internet service provider connection. However, this Wi-Fi coveragehas a limited distance for which the signal can remain strong and active. This signal strength is tested by using USB to UART converter connected to it and test based on two conditions, which are between the indoor of the building, and the outdoor. Outdoor distance is expected to be higher but with a Line-Of-Sight (LOS) factor, while indoors would be shorter since we would be factoring the presence of obstacles between the user and the IoT board. The Receiver Signal Strength (RSS) Test is measured in decibels per meter (dBm). Below are the tables and graphs for both the indoor and outdoor tests.

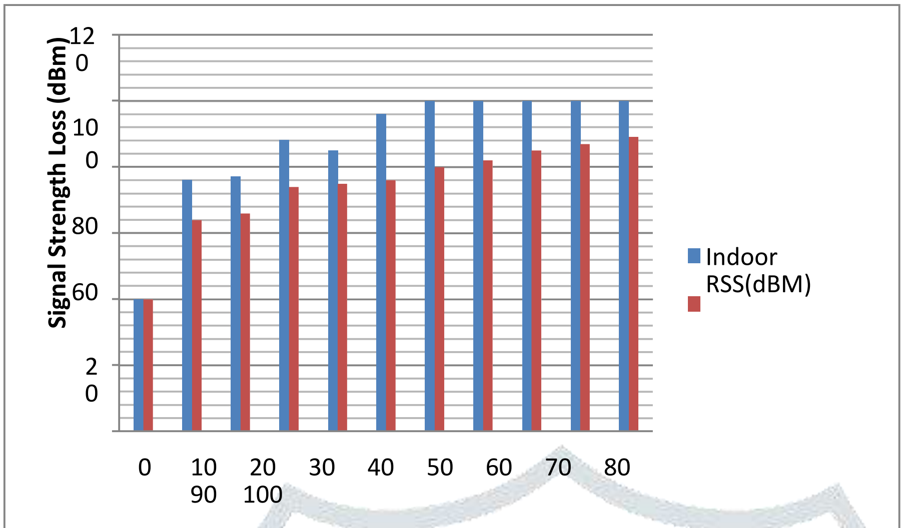

Figure 7: Graph illustrating the Receiver Signal Strength Loss of the ESP8266 against Distance

From the Graph in fig.7, it can be seen that the Loss of Signal is stronger indoors than outdoors. This is majorly due to line of sight and obstacle conditions. However, this is the performance of the IoT board without internet connection; which makes the results all the more impressive because the board is accurate for up to 40 meters indoors with obstacles, and is efficient for over a 100 meters in distance without obstacles and at LOS conditions. With internet connection, this efficiency is exponentially improved as the board can communicate anywhere in the world with internet service.

ESP8266 webserver sends the data collected to the cloud, which has been connected with the help of the ESP8266-01 module, whose function is to connect the sensory system to the internet/wifi. When a substantial amount of gas leak is detected, an alarm signal is activated to inform consumers. Simultaneously, under the monitoring section via the website known asThingspeak, the user will be notified of a leak and requested to take quick action. Figures 8 and 9 show the successful webserver data display via the ESP8266 to the Thingspeak site.

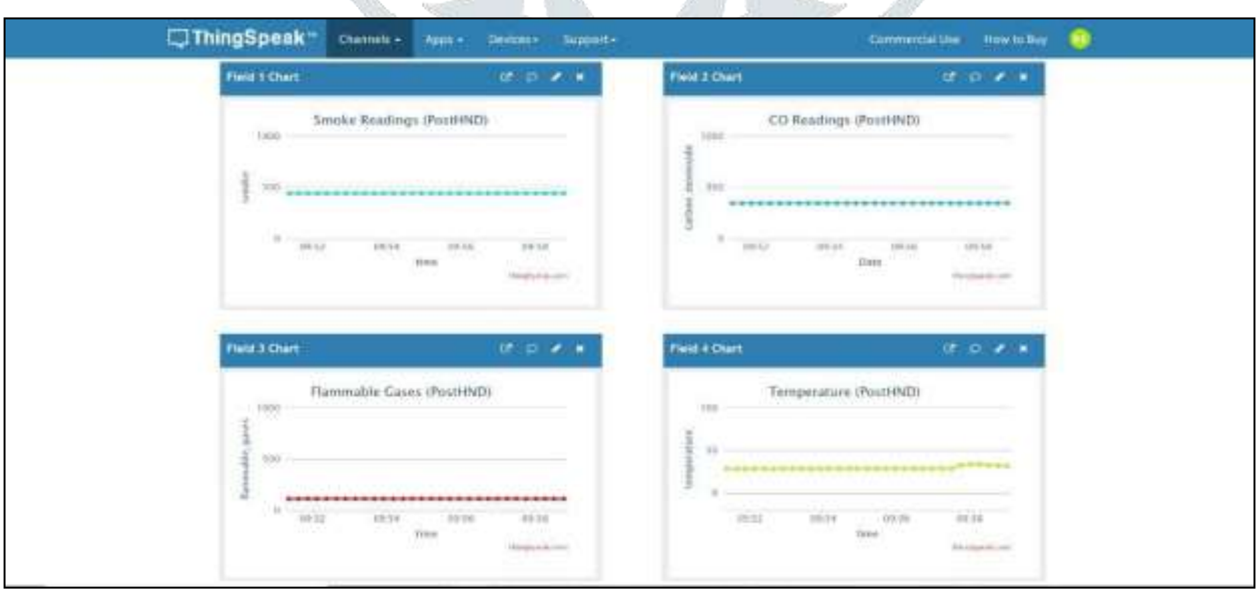

Figure 8: The System's Thingspeak Graphic User Interface

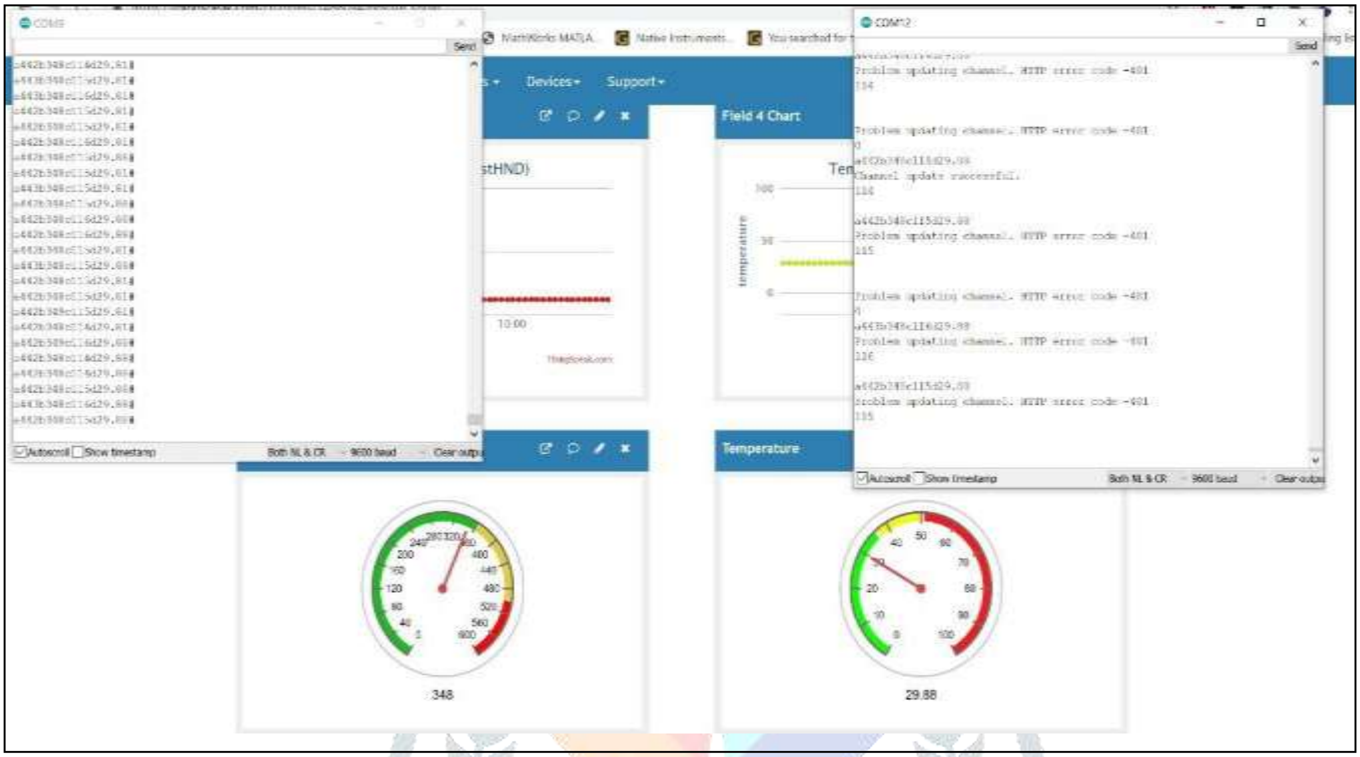

Figure 9: Web Server Gas Detection Data transmission in Progress

Conclusion

This project was aimed at developing an Internet of Things-based Flammable Gases and CO Monitoring and control in Remote Locations using a Webserver. The system is designed to monitor the intensityof gases such as methane, smoke containing carbon monoxide in remote locations and displays this data on a webserver. Its major significance is to enable early detection of the presence of these gases in the environment and send an alert to the user indicating a leakage or possible fire outbreak. The system also, grants the user the ability to send a control signal to a relay which conceptually controls a valve where the gas flows from. This system as a whole was designed to ensure safety of lives and property from the explosion and poisonous gas pollution. The system made use of a combination of the MQ 5 & 7 sensors for the flammable gases and Carbon monoxide (CO) respectively; and the DS18B20 sensor for temperature. These sensors were integrated with the IoT-enabled ESP8266 microcontroller board. The ESP8266 facilitates thetransmission of danger alerts and sensor readings through the internet via a dedicated web server which the user can then access remotely from anywhere in the world.

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