Implementation of a Smart Fire Management and Gas Leakage Control System with User Alert using Raspberry Pi3

Dr. Dhiraj Sunehra

Professor
Department of Electronics & Communication Engineering
Jawaharlal Nehru Technological University Hyderabad, Hyderabad, India

Abstract : Constant monitoring of the environment is required to minimize the damage caused in the event of a fire accident in a building or industry. Damage caused to the property due to adverse climate, pollution or theft can be recovered. However, material destroyed by fire is gone forever. In this paper, a prototype smart fire management and gas leakage control system is proposed using Raspberry Pi3. The fire detection system uses various sensors such as IR flame sensor and DHT11 Temperature and Humidity sensor for detecting any fire. Gas leakage detection is performed using MQ2 gas sensor. When a fire occurs, mains power is turned off to avoid short circuit. An exhaust fan is used to extract the smoke. Automatic water sprinklers are used to increase the overall fire safety and are significant to any fire management system. A water sprinkler can control fire advancement within few minutes, which will result in significantly less damage. In this work, an automatic water sprinkler system is built, which is activated as soon as fire is detected. Whenever any harmful gas leakage occurs in the transmission pipes, say in an industry, the solenoid valve is automatically turned off to avoid the leakage of gas from the damaged pipes. A buzzer provides sound alert, when a fire accident and/or gas leakage occurs. In the proposed fire management system, an alert is sent to user email along with a web link to access live streaming of the affected site. A webcam is used at the site for this purpose.

Index Terms **- Raspberry Pi3, IR flame sensor, DHT11 sensor, Smoke detector, Water sprinkler, Exhaust fan, Buzzer, Email alert, Webcam.**

I. INTRODUCTION

India has a history of major fire breakout in several places such as Kolkata, Sivakasi in Tamil Nadu, Delhi, Meerut, Bihar and Haryana. These fire accidents occurred in fire cracker factories, cinema halls, commercial complexes, school buildings and hospitals.

Every year 30% to 35% of accidents in industry occur due to fire and gas leakage, and several innocent people loose their lives. The Bhopal gas leakage incident was an industrial disaster occurred on 2nd December 1984 at the Union Carbide India Limited (UCIL) pesticide plant. Over 5,00,000 people were exposed to toxic methyl isocyanate (MIC) gas. A total of 3787 people died due to the gas leakage (https://timesofindia.indiatimes.com/topic/bhopal-gas-tragedy).

Several residential areas also are affected by fire accidents and gas leakage accidents every year. Due to this reason, automatic fire and gas detection and control has become very essential to reduce the fire and gas leakage accidents in the residential areas and industries. In this paper, we propose a smart fire management and gas leakage control system with user alert using Raspberry Pi3 processor. This type of system can be employed within buildings and industry to reduce the damage resulting from fire and gas leakage accidents.

II. LITERATURE REVIEW

Giandi and Sarno proposed a fire detector based on fuzzy logic and gas leakage concentration to predict the occurrence of fire in real time [1]. Sathyakala et al used computer vision technology to detect occurrence of fire. A surveillance camera is used for continuous monitoring and a video alert is sent to the remote fire station [2]. Ahmed Imteaj et al have used Raspberry Pi and multiple Arduino integrated to sensors and camera to detect fire. The system sends a message along with an image of the affected region with its location [3]. Shariq Suhail et al developed a multi-functional home security system using various sensors, GSM and email to alert the user [4]. Fraiwan et al proposed a wireless home safety gas leakage system that checks the change in concentration of gases and raises an audio visual alarm if the change in concentration has exceeded a predetermined threshold [5]. In the fire management and gas leakage control system proposed in this paper, various sensors are used to detect any fire or gas leakage, and an appropriate sound and email alert is sent to the owner along with a web link for live streaming of the affected site. An automatic water sprinkler system is built to reduce the damage due to the occurrence of the fire accident. Also steps are taken to turn off the mains power to avoid short circuit, and an exhaust fan is used to extract the harmful gases and also turn off the solenoid valve connected to the gas transmission pipes.

III. HARDWARE DESCRIPTION

3.1Block Diagram of the System

Figure 1 shows the block diagram of smart fire management and gas leakage control system. Here, we have used Raspberry Pi3 as the controller. The IR flame sensor, DHT11 (Temperature and Humidity) sensor, MQ2 smoke detection sensor are connected to the input pins of Pi. The IR flame sensor is used to detect occurrence of any fire. DHT11 sensor is used to measure the temperature of the surroundings when fire occurs; MQ2 sensor detects presence of any harmful gases such as methane, LPG, hydrogen and carbon monoxide due to gas leakage. When a fire is detected, Raspberry Pi turns off the mains power supply, turns on the exhaust fan, and activates the water sprinkler to reduce the damage to the property and materials. In case of gas leakage, solenoid valve is turned off to prevent further leakage of gas from the transmission pipes, exhaust fan is turned on to extract the

smoke from the closed area. Block indicated as R1 are relays. In both incidents, a buzzer is used to alert the humans present in the building, and an email is sent to alert owner/fire fighters, with a web link to access the web cam placed at the affected area for live streaming purpose.

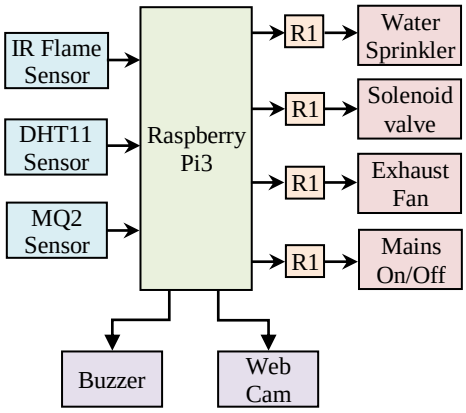

Fig. 1 Block Diagram of Smart Fire Management and Gas Leakage Control System

3.2 Raspberry Pi3 Computer

Raspberry Pi3 Model B single board computer consists of Broadcom BCM2837 64-bit Quad Core Processor running at 1.2 GHz (Fig. 2). It has a 40 pin extended GPIO, 1 GB of RAM, four USB2 ports, one HDMI port and one 100 Mbps Ethernet port [6]. Raspberry Pi does not have an internal hard disk. It has a Micro SD card port for loading the operating system (OS) and storing data. It supports different type of operating systems like linux and unix. Raspberry Pi3 also has a BCM 43438 Wireless LAN and Bluetooth Low Energy (BLE) on board.

Fig. 2 Raspberry Pi3 Model B Board

3.3 IR Flame Sensor

The flame detection sensor can detect a flame or light source having wavelength in the range of 760 nm-1100 nm (Fig. 3). It operates with a DC voltage of 3.3 - 5.0 V. The output can be analog voltage or digital (0 and 1). The detection angle is about 60°. The flame detection distance is about 0.8 m for lighter flame. If the flame intensity is higher, the detection distance is increased. The onboard digital output can be directly interfaced to the Raspberry Pi. Proper care should be taken to keep certain distance between the flame and sensor, otherwise it may burn out the sensor module.

Fig. 3 IR Flame Sensor

3.4 DHT11 Temperature and Humidity Sensor

In the proposed smart fire management and gas leakage control system, a DHT11 temperature and humidity sensor is used (Fig. 4). Here, we are taking only temperature values from DHT11 and neglecting the Humidity values. DHT11 contains two components, viz. :

a. Negative Temperature Coefficient (NTC) Temperature sensing component (Thermistor)
b. Pressure sensing components

The DHT11 has a negative temperature coefficient component such as thermistor. A Thermistor is a variable resistor, its resistance decreases with increase in the temperature of the atmosphere. Thermistors are made with semi-conductive materials like ceramic or polymer material [7]. These materials provide large variation in resistance when there is a small change in temperature giving better sensitivity.

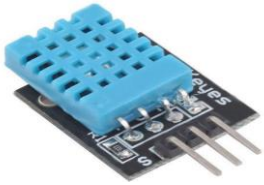

Fig. 4 DHT11 Temperature and Humidity Sensor

3.5 Gas Detection Sensor

A gas detection sensor such as MQ2 is used to detect the gas leakages from the gas storage tanks or the gas transportation pipes (Fig. 5). By using gas detection sensor we can detect particular gases like CO_2, LPG, methane, propane, etc [8]. These sensors also detect the smoke which is released from the harmful gases. When it detects any gas leakage from tank or pipe, its output goes to high (logic 1), and that signal is sent to Raspberry Pi.

Fig. 5 MQ2 Gas Detection Sensor

3.6 Solenoid valve

Solenoid valve is the electronic gate valve, which is used to control the flow of gas in transmission pipes. If the solenoid valve is in OFF state, its open to the flow of the gas. When it is in ON state, it stops the flow of gas. Solenoid valves works on AC power as well as DC power, but in this work, we have used a DC powered solenoid valve. Relay driver is used to trigger the solenoid valve based on Raspberry Pi instructions. Figure 6 shows the solenoid valve.

Fig. 6 Solenoid valve

3.7 Water Sprinkler

Water sprinkler consists of a water pump, a pipe and sprinkler. Water pumps are available in AC and DC power supply. In this work, water pump operating on a AC motor is used. The following are the specifications of the AC water pump.

Specifications:

- Operating Voltage : AC 230V, 50 Hz
- Operating Current : 2A
- Maximum flow : 350 Lt. / Hour
- Brushless

3.8 Buzzer alarm

Buzzer is a piezoelectric sound component, and which makes a sound when we want alerts. The piezoelectric components work on the electromagnetic principle. Buzzers work both with AC and DC power supply. But in embedded systems, we commonly use DC powered buzzers. The main application of the buzzer in the project is to indicate the alerts from fire and gas accidents. Figure 7 shows the buzzer.

Fig. 7 Buzzer

3.9 Exhaust Fan

In general, the exhaust fans are used to remove the hot air, or smoke in closed room areas. Normally all fans rotate in clockwise direction, but exhaust fan run in reverse direction means that anti-clock wise direction. Exhaust fans also work with AC supply as well as DC supply. Here we have used a DC powered exhaust fan. The main purpose of the exhaust fan is to remove the smoke and gas in the closed areas. Figure 8 shows the exhaust fan.

Fig. 8 Exhaust Fan

3.10 Web Camera

Web camera output is fed as an input to the Raspberry Pi. It is interfaced with Raspberry Pi through USB port. Camera is used to capture pictures and for video streaming. In this system, we are using web camera for video streaming, when a fire accident occurs in the home or work place. The video streaming can be accessed by typing IP address in the web browser. A webcam is shown in Fig. 9.

Fig. 9 Webcam

3.11 Relays

Relays are switching devices. By using relays, we can close the switch or we can open the switch according to the application. Relays are electromagnetic devices. Relays are also used for to triggering the low power loads. Figure 10 shows the relay module.

Fig. 10 Relay module

IV. SOFTWARE TOOLS

Raspberry Pi supports Python language for developing the program. ExtraPuTTY tool is used to remotely access the Raspberry Pi.

4.1 Python language

Python is an advanced programming and scripting language, which contain thousand of predefined libraries. Due to this, we can easily develop programming codes compared to other languages. Python language works on the Windows platform as well as Unix system. By using python language, we can also create a single line code. As compared to the other languages python take less amount of place and less code to perform the same operation.

4.2 ExtraPuTTY

The Raspberry Pi3 board is remotely accessed by using ExtraPuTTY application. ExtraPuTTY is the open source application. It provides connection or transfer the data between the Raspberry Pi and server, which creates a virtual connection between the Raspberry Pi and server. ExtraPuTTY software supports different type of network protocols such as SCP, SSH, TELNET, HTTP, TCP, UDP, and FTP [9]. In this protocol, we are using SSH to communicate with Raspberry Pi. Figure 11 shows the configuration page of the ExtraPuTTY.

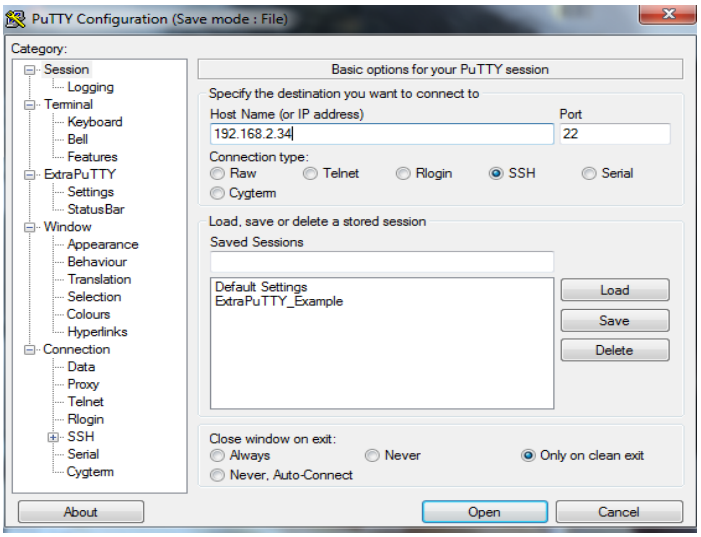

Fig. 11 ExtraPuTTY configuration page

V. SCHEMATIC DIAGRAM

Figure12 shows the schematic diagram of the smart fire management and gas leakage control system. Raspberry Pi3 consists of 40 pins and 4 USB ports. The 40 pins include 26 GPIO pins and 14 system supported pins.

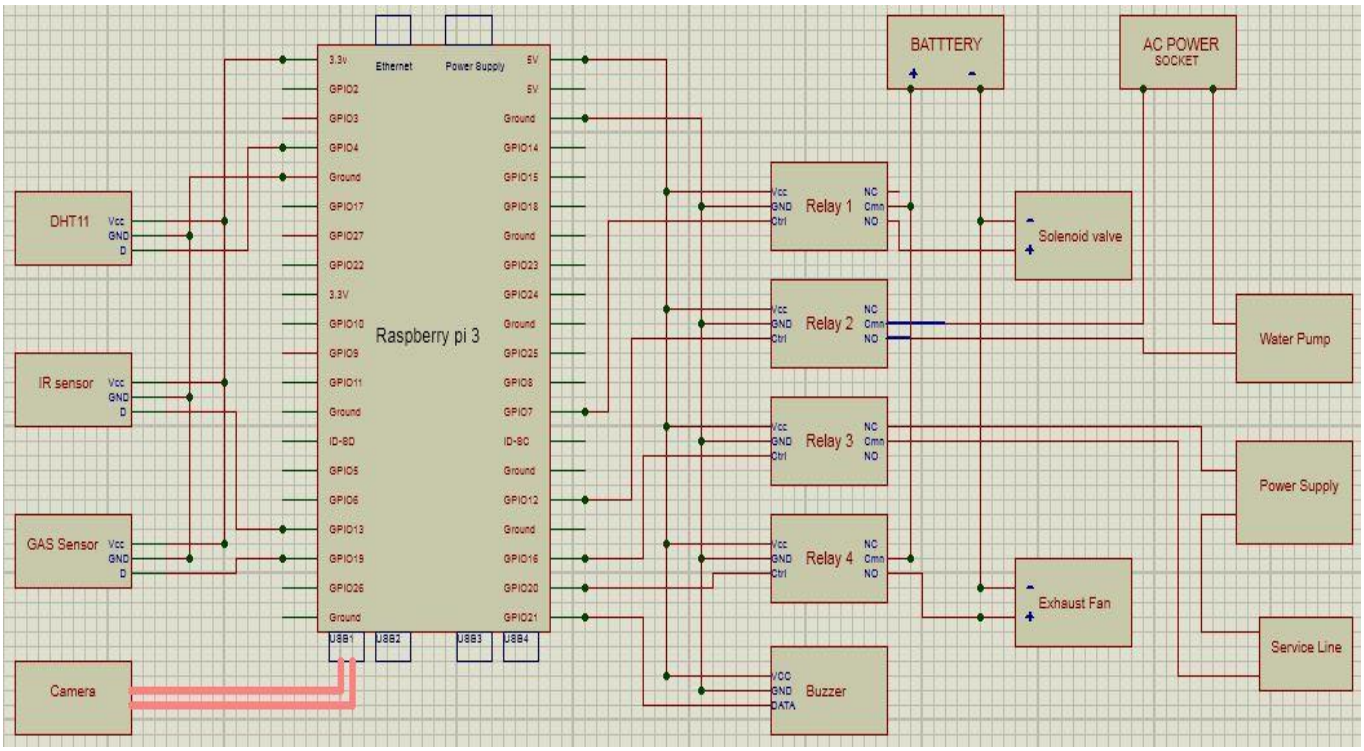

Fig. 12 Schematic Diagram of the System

VI. EXPERIMENTAL SETUP AND RESULTS

6.1 Experimental Setup

Figure 13 shows the experimental setup of the smart fire management and gas leakage control system. Figure14 shows the top view of the experimental board.

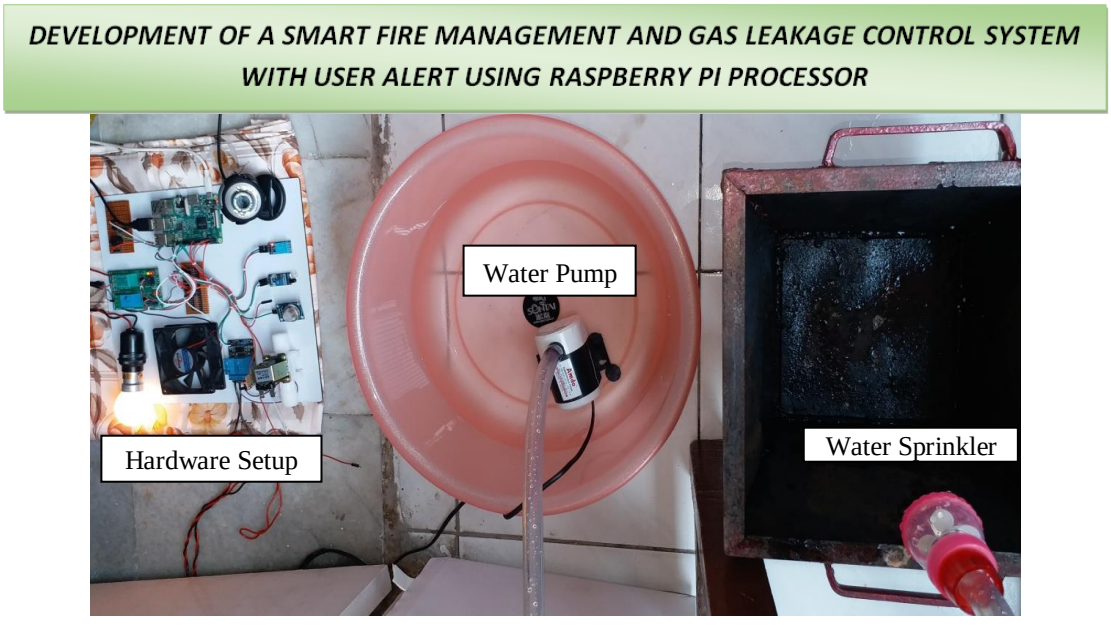

Fig. 13 Complete Experimental Setup of the system

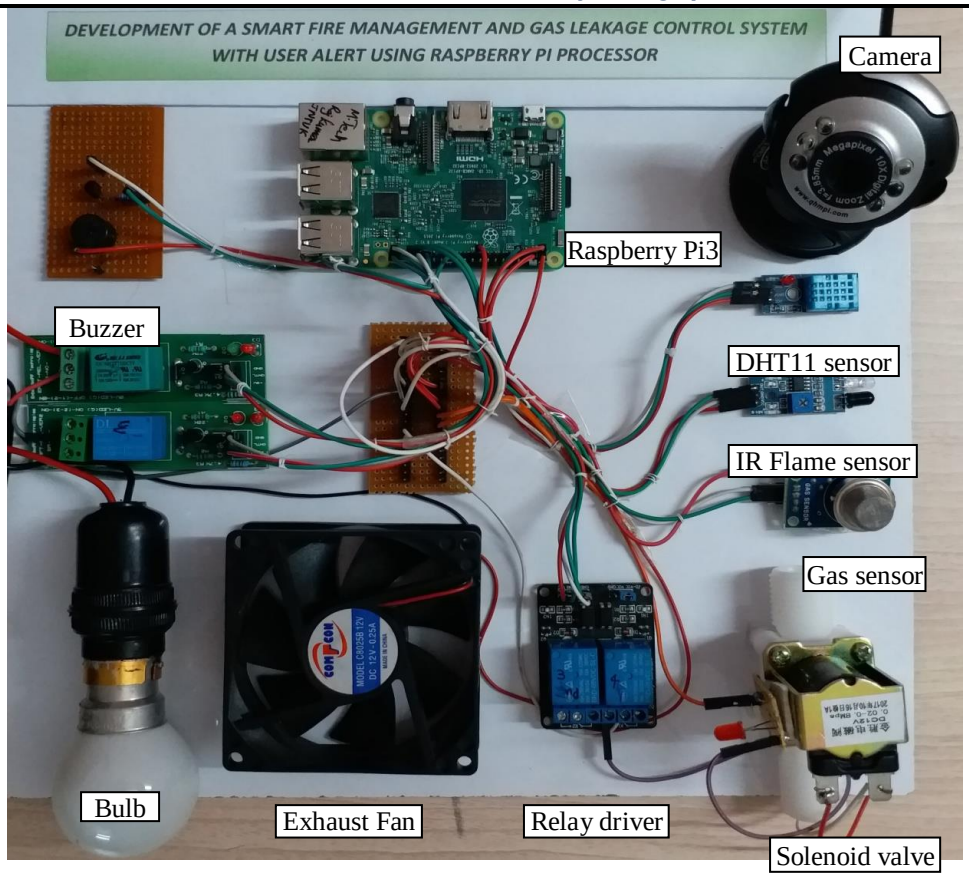

Fig. 14 Top view of Experimental Setup of the system

The experimental setup consists of various input and output devices where sensors are input devices. These include IR Flame sensor, DHT11 sensor and Gas leakage detection sensor. Water pump, exhaust fan, electrical bulb, buzzer, solenoid valve and camera are output devices. All the input and output devices are connected to the Raspberry Pi and controlled by the Raspberry Pi. Input sensors give signals to Raspberry Pi and it operates the output devices according to the input signals. To test the experimental setup, manually we provided flame and gas leakage in front of relevant sensors. Once we cause flame and gas leakage to occur near the sensors, the sensors detect the flame and gas leakage and give information to the Raspberry Pi. The threshold value needs to be set in the sensors so that they detect the flame and gas. According to that information, Raspberry Pi operates water pump, exhaust fan, solenoid valve, electrical bulb and buzzer through the relay drivers.

6.2 Results and Discussion

The following sections describe the results about the two different cases investigated in the experimental setup.

a. Fire detection and security system
b. Gas leakage detection and security system

6.2.1 Fire Detection and Security System

Under the normal condition, light is ON, exhaust fan and buzzer are OFF, and the water pump and sprinkler are OFF. The IR flame sensor is used for detecting flame in the work place. It gives digital signal (logic 1) to the Raspberry Pi when fire flame is detected. Then Raspberry Pi checks the temperature of the surrounding by using DHT11 sensor. For testing purpose, we manually create a fire in front of the flame sensor with the help of a lighter.

Once we keep the lighter in front of the sensor (Fig. 15), the flame is sensed by IR Flame sensor and logic 1 is sent to Raspberry Pi. Raspberry Pi checks the temperature provided by DHT11 sensor. If the temperature value is below the rated value, 45°C, Raspberry Pi ignores the flame alert. If the temperature value is above 45°C, Raspberry Pi turns on the safety system as follows:

- Turn ON the Water Pump
- Turn ON the Exhaust Fan
- Turn OFF Mains Power supply
- Turn ON the Buzzer
- Send E-mail Alert to user with camera live streaming link

Fig. 15 Experimental Setup with Water Sprinkler when fire occurs

We are using DC powered Exhaust Fan which works on the DC 5V power supply which is used to remove the smoke created by the fire in the closed areas. This is helpful to minimize the fire effects in the closed paths. Sometimes fire accidents occur due to the electrical short circuits, so it is necessary to shut down the power when fire occurs. In this setup, we also develop a program to give the alerts to the user about the accident in the two ways. Those are:

a. Buzzer Alert
b. E-mail Alert

Buzzer draws power from the Raspberry Pi. It gives the sound to alert the user. Sometimes user may be outside of work place, it is difficult to know about the accident, so we have included an E-mail alert also to the user with a web link for accessing the camera and live streaming of the fire site. Figure 16 shows the Fire accident email alert sent on the user mobile.

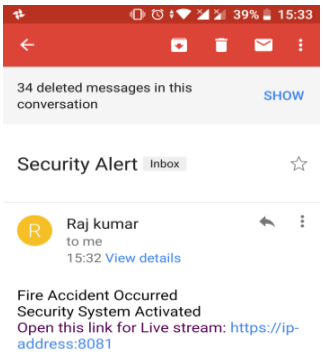

Fig. 16 Email alert sent to user on occurrence of fire accident

We are using a web camera for live streaming. It is directly connected to Raspberry Pi through the USB cable. By clicking the link provided in the mail, user can directly watch the work place. According to this user can take further steps. Figure 17 shows the live stream image from web camera when fire occurred. The fire security system is deactivated automatically when fire is totally removed from the work place.

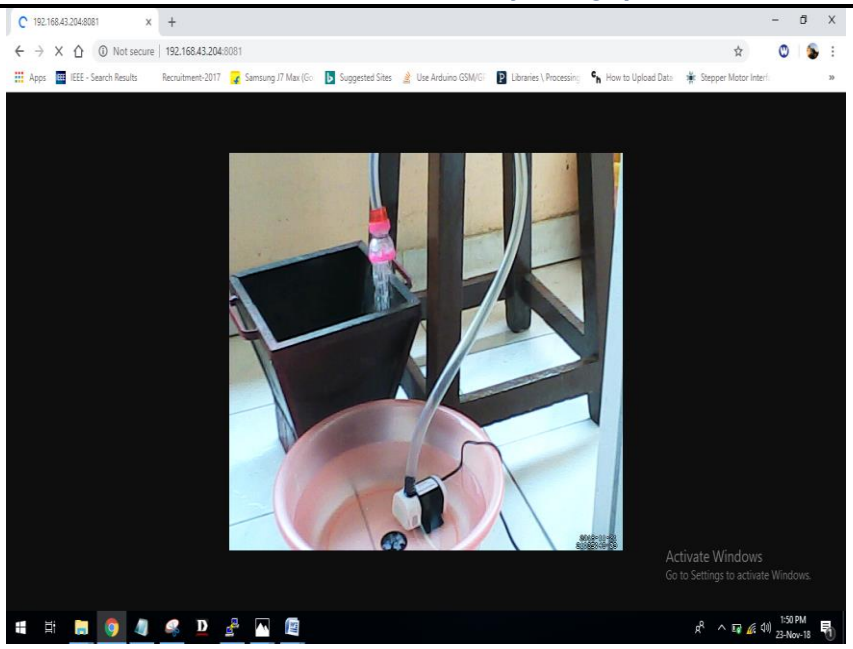

Fig. 17 Image captured by Webcam of fire accident site

6.2.2 Gas Leakage Detection and Security System

We use gas leakage detection sensor to detect the gas leakage, solenoid valve to stop the flow of gas in the pipes, exhaust fan to remove the gas in the closed areas. It is also necessary to give an alert to the user about the accident. So, we employee a buzzer and also provide an E-mail alert to the user as part of the developed system.

We are using DC powered gas leakage detection sensor, which works on 3.3V DC power taken from the Raspberry pi. It gives output in digital form. The sensor value is '0' means there is no gas leakage in the work place and '1' means gas leakage occurred in the work place. When we place an incense stick near the gas sensor, it gives a signal 'logic 1' to the raspberry pi. According to that sensor signal, raspberry pi controls the output peripherals and activates the security system as follows:

- Turn ON solenoid valve
- Turn ON the Exhaust Fan
- Turn ON the Buzzer
- Send E-mail Alert to user with camera live streaming link

Gas leakages may occur from pipe joints or cracks developed at the welding joints. So we place the gas sensor at the place of pipe/welding joints. If we want to protect total pipe line, we need multiple sensors based on the length of the pipe line, because sensor sense only limited area. We are employing a solenoid valve to control or stop the flow of gas in the pipe lines when gas leakage occurred. In normal condition, it is open to flow of gas. Once it is turned on, it stops the gas flow. Solenoid vale act as a electronic switch. It works on the DC power as well as AC power. We are using DC powered solenoid valve. If gas leakage happened in one place along the pipe line, the previous solenoid valve is closed, so that gas leakage is minimized. Raspberry Pi turns on the solenoid valve through the relay driver based on sensor information. Once relay triggers the valve, it stops the flow of gas. Due to this action, we can minimize the gas leakage in the pipe. There is a chance for occurrence of the blast, if the gas accumulates in a closed area. So it is necessary to remove the gas in the closed area using an exhaust fan. Along with the solenoid valve, raspberry pi also turns on the exhaust fan to remove the gas in the closed areas and Pi does not turn off the main power supply because it is independent to the gas leakage as shown in Fig.18.

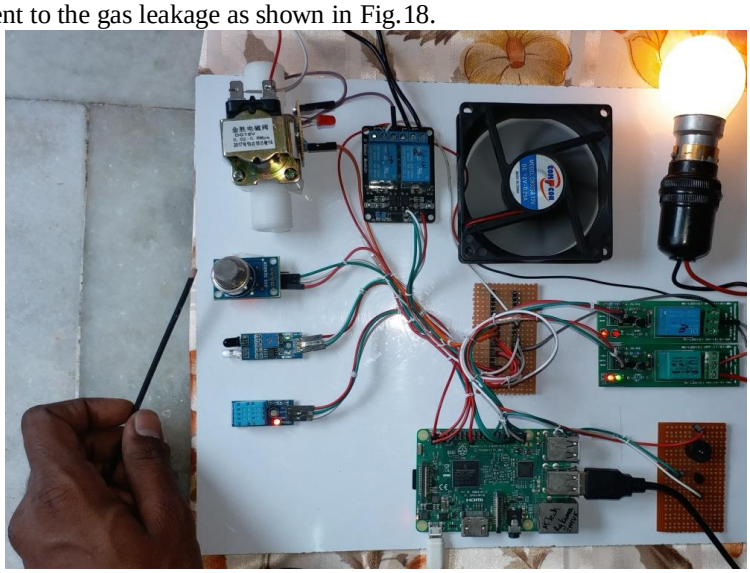

Fig. 18 Top view of experimental board under Gas leakage condition

Buzzer gives the alert when a gas leakage has occurred. In the E-mail alert, we are giving information about gas leakage and also provide a web link to access the web camera for live steaming of the gas leakage site. If user wants to see the work place, he can just click the provided link. Figure 19 shows the E-mail alert message for gas leakage.

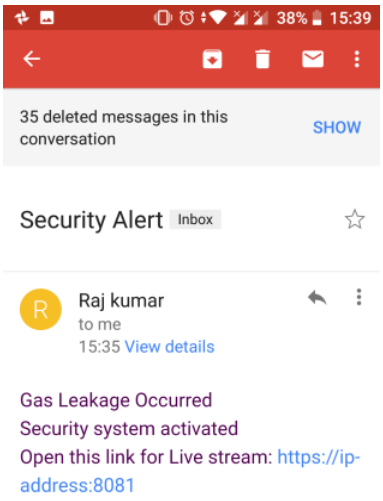

Fig. 19 Email alert to user on occurrence of Gas leakage

VII. CONCLUSIONS

In the prototype fire management and gas leakage control system with user alert, Raspberry Pi3 processor is used along with various sensors for fire and gas leakage detection, and control devices such as water pump, solenoid valve, and exhaust fan. The system can be used to control the fire occurrence and gas leakage in a relatively lesser period of time, with the maximum rate of true fire detection because we are employing IR flame sensor along with DHT11 with the suitable threshold value. AC powered water pump along with sprinkler is very much suitable and economical compare to other water sprinklers. The solenoid valve is used to stop the gas flow in pipe lines when gas leakage occurred. Exhaust fan is used to clear the gas and smoke in the closed areas. The user alert system is employed in two ways, viz. buzzer and E-mail alert. E-mail contains the link to access the camera for live streaming of fire caused and gas leakage area.

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