Wireless Gas Leakage Detection System using Microcontroller and GSM SIM900

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***Abstract*— Gas leakage can be dangerous to the human by explosion, fire and asphyxiant. In chemical laboratory, gas leakage can harm the people in the area. However, there is no gas leakage detection system for chemical laboratory. The need of efficient gas leakage detection system in laboratory is important to avoid the dangerous situation to the people. In this paper, a wireless gas leakage detection system is developed to be applied in the chemical laboratory. The methane and butane gas were used in this project to test the system. The developed system consists of three main parts. It is Arduino Uno R3, MQ-9 gas sensor and alert system. The alert system consists of buzzer, DC fan and GSM Shield. The system is implemented in Arduino environment using C programming. Arduino and gas sensor is used to detect the gas leakage of natural gas. Conductivity level for gas sensor is standardized at resolution of 45. The detection starts when sensor read the changes of conductivity gas and trigger the buzzer and fan when exceed the reference value. Then, system simultaneously sends the alert message to inform the technician about the leaks of gas. In this project, the output voltage is representing the changes of concentration and conductivity level of gas. The system is successfully implemented and achieved the objective of the project.**

***Index Terms*—arduino uno r3, gas leakage detection, gsm shield and mq-9 gas sensor.**

I. INTRODUCTION

The uses of the natural gases are more widespread along with the revolution of the technology. The natural gas is including methane, propane, butane and etc. The natural gas is widely used in homes as a compressed natural gas (CNG). CNG are mostly used in heating, lighting fixture and other appliances at homes. The usage of this gas also is commonly at an indoor environment like chemical laboratory [1]-[2].

Although the natural gas is widely used, it also can caused harm to the human such as personal injury and property damage [3]. This gives major disaster to the human if it exploded and causes a fire. The leakage of this gas also can affect the human health by asphyxiant. Thus, the gas leakage detection system is important to prevent all of this from happened [4]-[5].

Latest technology of gas leakage detection system mostly is applied at home [6]-[7]. There is no efficient gas leakage detection system applied in the chemical laboratory. This paper proposed the wireless gas leakage detection system using microcontroller and GSM SIM900. This system consists of Arduino Uno R3, MQ-9 gas sensor and alert system. The system introduced MQ-9 gas sensor which has a high sensitivity to the methane gas and GSM Shield to send alert message as a warning. This system is developed to be applying in the laboratory.

The system is operated using Arduino Uno R3 as a microcontroller. This system is tested with a methane and butane gas as a sample leakage gas. Once MQ-9 gas sensor detected the gas leakage, the alert sound is produced to give a warning to the user of the laboratory and the leaks of gas are blew away from the laboratory by the DC fan. In the mean time, the GSM Shield will send the alert message to the mobile phone of the technician.

This paper is divided into five sections. Section 2 explains about the structure of the system. Section 3 briefly explains the details about the system operation. Section 4 included the results and the discussions. Next, the last section which is section 5 is the conclusion from the overall explanation in the paper.

II. SYSTEM STRUCTURE

A. Components in the System

The designed of the system mainly has three major parts. It is namely Arduino Uno R3, MQ-9 gas sensor and alert system. The block diagram of the system is shown in Fig. 1.

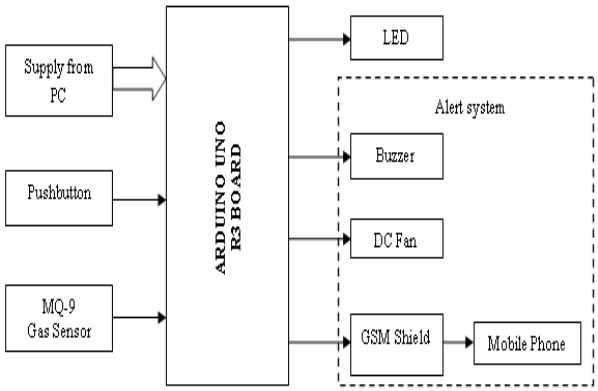

Fig. 1: Block diagram of wireless gas leakage detection system

B. *Arduino Uno R3*

The Arduino Uno R3 is a microcontroller board based on ATmega328 [7]. It's used as a controller in the system. It consists of 6 analog inputs pin and 14 digital input/output pins. Since the operating voltage for Arduino is 5V, it gets the supply from the PC via USB cable. As shown in Fig. 2, the input of the board is pushbutton, MQ-9 gas sensor and supply from PC.

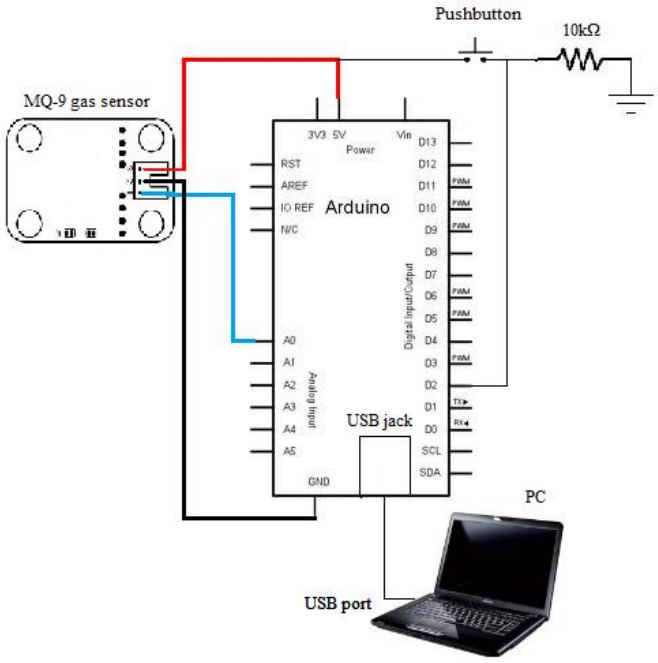

Fig. 2: Circuit of the input system

The pushbutton is a switch to ON and OFF the whole system. The analog input of Arduino is from the output of gas sensor. Sensor value is the output value of the sensor. The value is varying with the conductivity of the sensor. In Arduino environment, the sensor value is in unit of resolution. It is in range of 0 t0 1023. It represents the voltage of analog input between 0 and 5V [8]-[9]. The relationship of sensor value and voltage is represented in Eq. (1).

$$V = \frac{SensorValue}{Analog Steps(1023)} x V_{ref}(5V) \qquad (1)$$

In this project, the output of the system is LED and alert system. The LED is used to shows the state of pushbutton. The minimum circuitry of the output system is presented in Fig. 3. It only shows the LED and alert system without the GSM Shield.

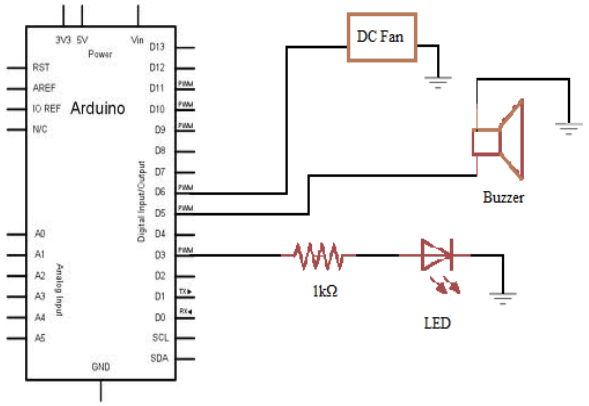

Fig. 3: Minimum circuitry of the output system

C. *MQ-9 Gas Sensor*

MQ-9 gas sensor is a semiconductor sensor with high sensitivity to the combustible gas such as methane, butane and propane. The conductivity of the sensor is higher with the rising of the concentration of gas. But, in the clean air, the conductivity of the sensor is low. In other word, the sensor is insensitive to air. So, this sensor is suited to apply in this system. Another feature of the sensor is long life and low cost. This sensor is easily interfaced to the Arduino board since it is compatible with it. In addition, this sensor works at 5V power supply same as Arduino. To ensure the sensor is working properly, it should be left heated according to the specific time in the datasheet. This specific time is called preheat time [10]. The change of the gas concentration is the output of the sensor which is in voltage [11].

D. *Alert System*

Alert system is a system which operates when sensor detects the gas and exceeds the resolution of 45 as a reference value. The system has an alarm to give the warning to the people in the laboratory. It is sound from the buzzer. The system also used the DC fan as an initial step in avoiding the life accident. It will blow the molecule of the gas away from that area. So, the people will have a time to take an action to solve the leakage problem in dangerous situation. The 12V DC fan is used in this system. Since the output voltage at the digital pin of Arduino is too small, it needs the other element to drive the fan. MOSFET transistor will act as an electronic switch to drive the fan by applying a voltage to one of its pin. In this design, the IRF520 Mosfet is used [8]–[12]. The circuit to drive the DC fan is shown in Fig. 4.

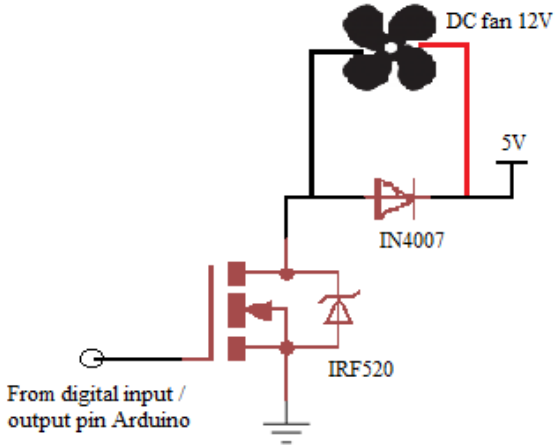

Fig. 4: Circuit of DC fan

The GSM Shield used in this system is Icomsat V1.1 SIM900 which compatible with Arduino. The shield is based on SIM900. It operates with a GSM wireless network. This system applied the wireless network from GSM Shield to send message once the system detect the gas. The shield is placed directly on the Arduino board. These shields get the supply of power from the Arduino. Hence, the connection of pin RX and TX from the shield should be connected to the correct pin at Arduino board to ensure the communication between both of board is in the right way. As shown in Fig. 5 below, the RX pin of GSM Shield is set to pin 5 whereas the TX is set to pin 4. In this system, the COM switch at the GSM shield should be always set to UART port [13]-[14].

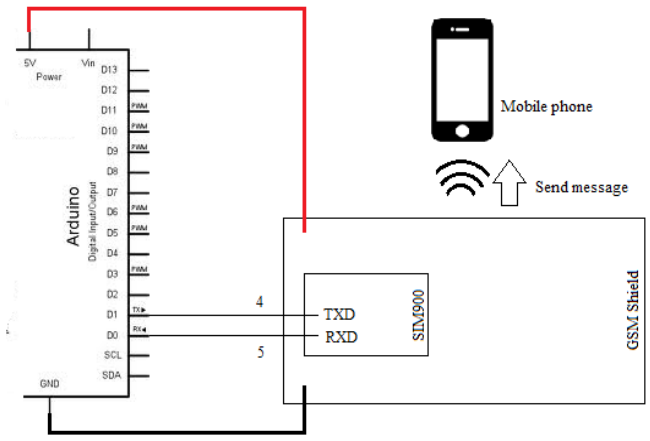

Fig. 5: Minimum circuitry of GSM Shield with Arduino

III. System Operation

The structure of wireless gas leakage detection system used the C language to operate the whole system. The language is written in the Arduino environment. Before uploading the programming, the driver for Arduino must be installed first [15]. It's important because the serial port for every computer is not the same. Serial port at Arduino Uno R3 is on digital pin 0 and 1. Pin 0 at Arduino is RX and pin 1 is TX. The serial communication is important to allow the communication of Arduino board with computer and other devices [16].

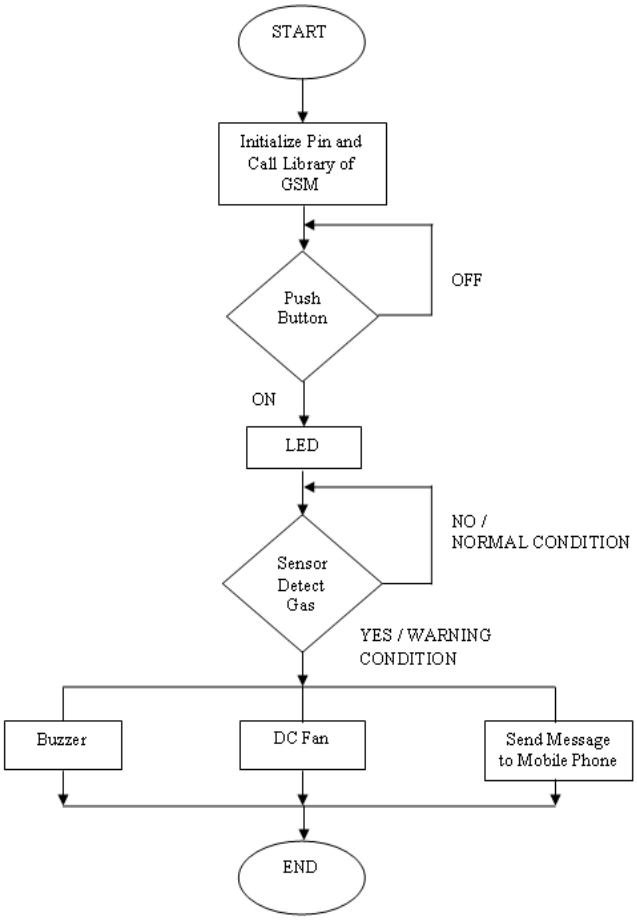

Fig. 6: Flowchart of wireless gas leakage detection system

Fig. 6 is shows the operation of the system. Once the Arduino board is getting supply from PC through USB cable, the system will be ready to use. It also supplied the power to GSM Shield. In the first stage, the system will be initialized the analog and digital pin. At the same time, the system will call the GSM Shield library. Then, the ON button at the GSM Shield should be pressed for a moment to power ON the shield. The RESET button at GSM Shield also should be pressed [13]. The system now is ready to the next stage.

In the second stage, the serial port is opens and baud rate for this system is set to 9600 bits per second. This system transmits the data with 9600 bits in one second. The digital output that connected at Arduino will set as output whereas analog input as input. The GSM Shield also started initialized its board based on the library. The system always at this stage until the pushbutton is ON.

During ON state, gas sensor will begin detect the presence of gas in the surround and display it in the serial monitor. The serial monitor will display the sensor value. It always display and compared that value simultaneously with the reference value in the programming. At the same time, the serial monitor will showed the status of the GSM Shield in standby mode.

Once the values exceed the reference value, the system is coming to the warning condition. Otherwise, the system is in normal condition. In normal condition, all components at

digital output are LOW. The GSM Shield still in standby mode. During warning condition, the Arduino board will transmits the HIGH signal to the digital output and supplied the voltage to it. Then, all components that are connected to the digital output will function except LED which ON once the pushbutton is ON. The buzzer start gives the warning to the surround people. The DC fan starts operate as a first steps to prevent the people in the surrounding. The wind from that fan will blow the gas molecule away from that area. So, the people have a time to take any an action to prevent the problem from becoming worse. At the same time, the GSM Shield will send the short message about the gas leakage to the technician. Once the technician received that message, the serial monitor will displays that the message is delivered. It's important to ensure the technician is received the alert message.

The buzzer and DC fan will functions till the authorized user turn OFF the system or the sensor value is decrease and below the reference value of the sensor. When the value of sensor is below the reference value, the system is back to the normal condition.

IV. Results And Discussions

The gas leakage detection system is tested in two different conditions. It is during normal condition and warning condition.

A. Normal Condition

Normal condition is the condition when the environment in the chemical laboratory is in clean air without the leak of gas. In this system, the normal condition is began after the preheat time. The preheat time took about 60s for the sensor value or the reading of the sensor to become stable. The prototype of the system during normal condition is shown in Fig. 7.

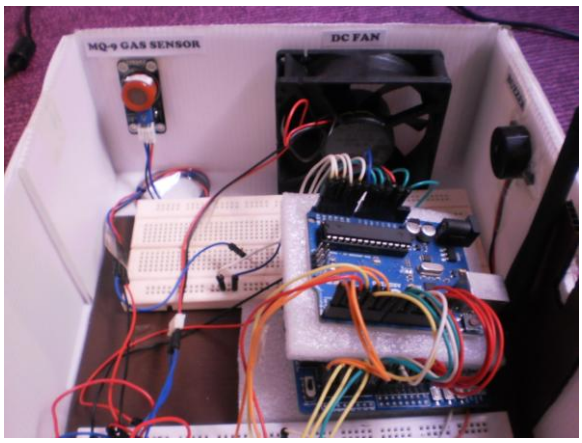

Fig. 7: System during normal condition

Table 1 show the sensor output varied with time during normal condition. For the first 60s after the system is ON, the sensor values are unstable because the sensor is under preheat time. During this time, the sensor is left heated until the value is stable. After 60s, the sensor value became stable and the sensor started to present the sensor value in normal condition. All the data from the table is tabulated in Fig. 8.

From Fig. 8, it can be seen that the sensor value is extremely increase for the first 10s. It is because the sensor start detected the changes of concentration gas from the surrounding. At 10s until 60s, the output of the sensor is unstable. The system become to the normal condition after 60s. This condition will maintain until the system or the sensor is exposed to the gas.

Table 1: Sensor output within preheat time and normal condition

Time (s)	Sensor Value (resolution)	Output Voltage (V)
0	0	0
10	47	0.230
20	40	0.196
30	36	0.176
40	30	0.147
50	30	0.147
60	27	0.132
70	27	0.132
80	27	0.132
90	26	0.127
100	26	0.127
110	26	0.127
120	26	0.127

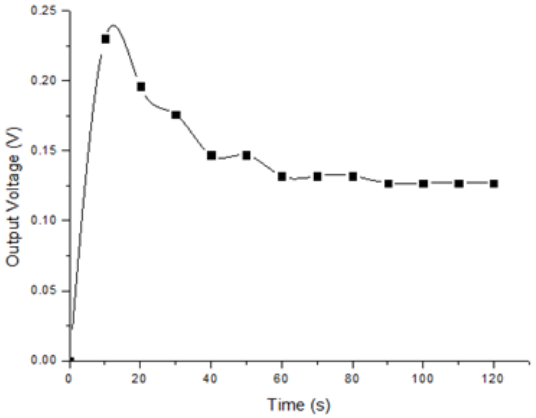

Fig. 8: The output voltage under normal condition

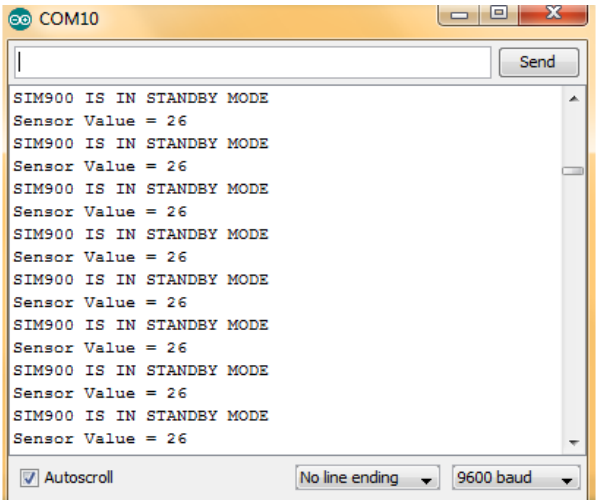

Fig. 9: Serial monitor in normal condition

By referring to Fig. 9, the graph shows the data on serial monitor during normal condition. The function of serial monitor is to display the serial data that are sent from Arduino board. In this case, the serial data will present the reading from the sensor represented by sensor value and stated the status of GSM Shield represented by SIM900. The sensor value is measured in terms of resolution. During normal condition, SIM900 is always in standby mode.

B. Warning Condition

Warning condition is the condition where the environment in the chemical laboratory is polluted with the leaks of gas. The prototype of the system during warning condition is shown in Fig. 10. During warning condition, the sensor will detect the leaks of gas and alert system is activated. Under this condition, the buzzer and the DC fan is in ON state. The GSM Shield will send an alert message to the technician's mobile phone. The wireless gas leakage detection system is tested with methane and butane gas under this condition.

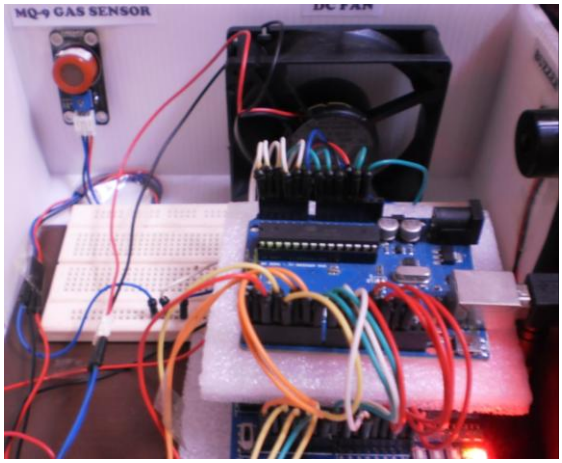

Fig. 10: System during warning condition

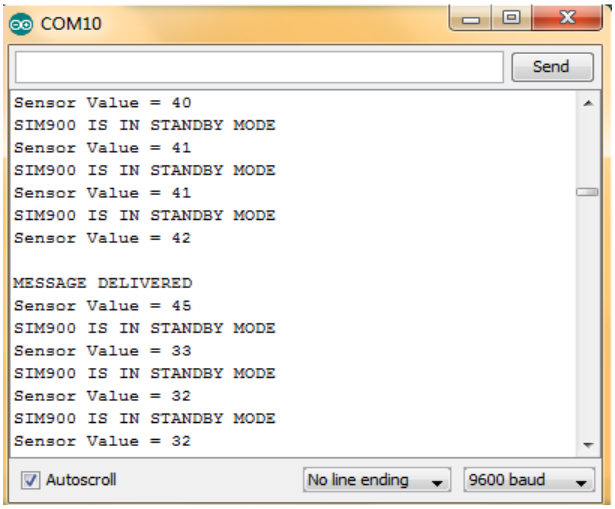

Fig. 11: Serial monitor in warning condition

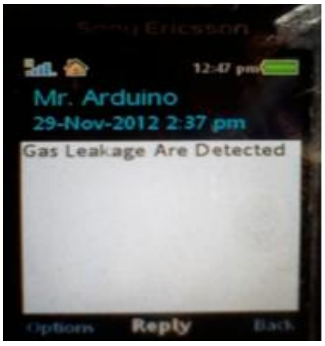

Fig. 12: The alert message sent by SIM900

The serial monitor in Fig. 11 shows the sensor value and the status of SIM900 during warning condition. In this case, the reference value for the sensor value is set to 45. Value of 45 indicated that the air in the laboratory is polluted with the leakage of gas and could harm the human being in the area. Once the sensor detected the presence leakage gas and the sensor value is exceeded the reference value, the buzzer is automatically ON and about 10 seconds of delay, the DC fan also ON. And at the same time, an alert message is delivered by SIM900 to the technician's mobile phone as shown in Fig. 12. Meanwhile the serial monitor will show that the message is successfully delivered.

Firstly, the system is tested using methane gas but under two different conditions. First condition is when the system is tested with methane gas without DC fan in the system. Second condition is when the system is tested with methane gas with the DC fan in the system. Both conditions are tested within 5 minutes. The output voltage of the system when tested using methane gas under conditions without and with DC fan are summarized in Table 2. The output voltages for both conditions are then plotted in Fig. 13.

Table 2: Output voltage under warning condition tested with methane

Time (s)	Output Voltage (V)	
	With DC fan	Without DC fan
0	0	0
20	0.254	0.267
40	0.205	0.205
60	0.132	0.127
80	0.127	0.127
100	0.127	0.127
120	0.127	0.127
140	0.274	0.283
160	0.283	0.484
180	0.630	0.630
200	0.968	0.978
220	1.173	1.173
240	1.266	1.266
260	1.134	1.315
280	0.982	1.237
300	0.914	1.207

Based on the Fig. 13, the output voltage from the sensor where the system has no DC fan presented a higher value compared to the output voltage from the sensor where the system comes with the DC fan. The sensor without DC fan

stated an output voltage of 1.207V after tested within 5 minutes. The value still larger than the output voltage from the sensor with DC fan which is 0.914V only. This happened due to the presence of the DC fan which helped to blow away the methane gas from the laboratory and kept the air in the environment clean from hazard gas and under safest condition. Thus resulted the output voltage from the sensor declined faster compared to the sensor without DC fan.

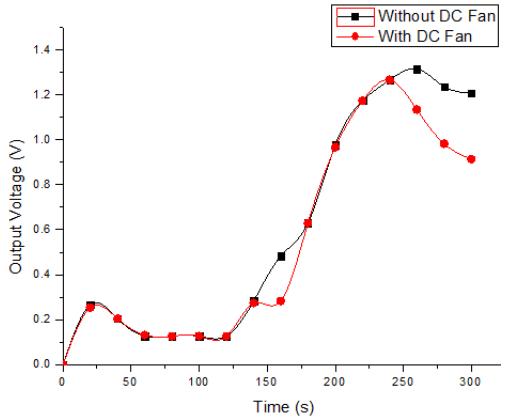

Fig. 13: Output voltage from the sensor when tested with methane gas under two different conditions

Next, the system is tested using butane gas under same conditions as the system is tested with methane gas. First condition is when the system is tested with butane gas without DC fan in the system. Second condition is when the system is tested with butane gas with the DC fan in the system. Both conditions are tested within 5 minutes too. The output voltage of the system when tested using butane gas under conditions without and with DC fan are summarized in Table 3. The output voltages for both conditions are then plotted in Fig. 14.

Table 3: Output voltage in warning condition tested with butane

Time (s)	Output voltage (V)	
	With DC fan	Without DC fan
0	0	0
20	0.235	0.235
40	0.147	0.147
60	0.127	0.127
80	0.127	0.132
100	0.127	0.127
120	0.127	0.127
140	0.161	0.171
160	0.186	0.235
180	0.230	0.269
200	0.269	0.332
220	0.308	0.386
240	0.371	0.425
260	0.430	0.484
280	0.455	0.503
300	0.406	0.459

Fig. 14 shows the output voltage measured from the sensor which has not have DC fan in the system and from the sensor with the DC fan in the system. The graph still showed the same finding as the earlier experiment where the sensor is tested with methane gas under two different conditions. The sensor without DC fan in the system stated an output voltage of 0.459V which is higher than output voltage from the sensor with DC fan where the value is 0.406V. From the results, it shows that the DC fan play an important part in this project. It acts as a device that could help to keep the environment under safe condition and prevent the worst outcome from happened by blew away the leakage gas within the lab.

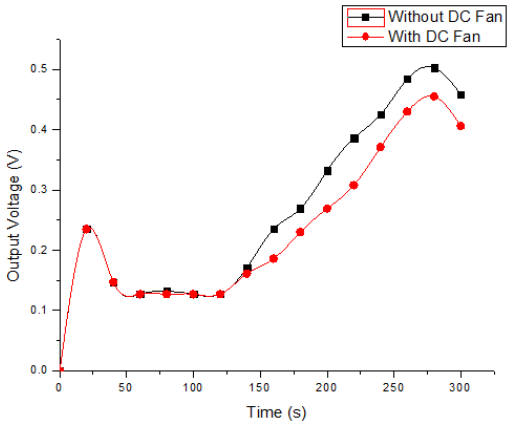

Fig. 14: Output voltage from the sensor when tested with butane gas under two different conditions

V. Conclusion

The system is reliable to detect the natural gas in the chemical laboratory. From the finding, it proves that the MQ-9 gas sensor is able to detect the leaks of gas in the chemical laboratory and trigger the alert system. So, the system is able to prevent the personal injury and property damage caused by the gas leakage. The gas sensor used in this system is not recognizing what type of gas is detected. Then, the coverage area of GSM Shield used in this system is in narrow range. Even though the system is reliable in detecting the leakage of gas, the system still needs some improvement for future development. The system is recommended to upgrade its system which can monitor more than one chemical laboratory. In the future, the system should be improved to control many indoor environments at one time. In addition, the system should use the gas sensor which can determine what type of gas is detected. So, it can help people to overcome the leakage of gas faster since they know what gas are leaks. Lastly, in the future work, the designer is recommended to use the GSM which covers the network in larger area. So, the bigger environment can be monitored. As a conclusion, this paper is successfully achieved the objectives and the system is reliable to apply in any environment to detect the leaks of gas.

References

[1] Mohamed Ridza Abdullah and Mohamad Nazran Basirun "ICLG TO: Gas Regulation 2011," in Malaysia, Mohamed Ridza & Co, 2011, ch. 22.

[2] Uses of natural gas. (Nov 27, 2012), Uses of Natural Gas in US Homes. Available: http://geology.com/articles/natural-gas-uses/

[3] Jinhao Sun, Yezi Li and Xiaojin Yan, "The design of automatic detection processing device of gas leakage based on MB95204K," *Electrical and Control Engineering (ICECE)*, 2011, pp. 1807-1809.

[4] "Safety Data Sheet Butane, Commercial Grade," Tesoro.
[5] "Material Safety Data Sheet for: Methane (CH4)," Voltaix.
[6] Abdul Hafiz bin Abdul Razak, "Interactive GSM based home security system", Universiti Kuala Lumpur British Malaysian Institute, 2012.
[7] Luay Fraiwan, Khaldon Lweesy, Aya Bani-Salma and Nour Mani, " A Wireless Home Safety Gas Leakage Detection System," *Biomedical Engineering (MECBME), 1st middle east Conference, 2011*.
[8] Massimo Banzi, Getting Started with Arduino, 3rd release, p. 26.
[9] Michael Margolis, Arduino Cookbook, O'REILLY, 1st edition, March 2011
[10] "MQ-9 datasheet," Henan Hanwei Electronics Co. Ltd, China.
[11] Kumen Blake, "Analog sensor conditioning circuit," Microchip Technology Inc, 2005.
[12] "IRF520 datasheet," Vishay Siliconix, Germany.
[13] "GSM / GPRS Shield Icomsat V1.1 SIM900 datasheet," Itead Studio, America.
[14] Arduino Forum. (October 30, 2012). Arduino + sim900 – Arduino Forum.Available: http://arduino.cc/forum/index.php/topic,102785.0.html
[15] Getting Started w/ Arduino on Windows. (November 5, 2012). Install the driver. Available: http://www.arduino.cc/en/Guide/Windows
[16] Reference. (October 16, 2012). Serial. Available: http://arduino.cc/en/Reference/serial