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Wireless Sensor Network on LPG Gas Leak Detection and Automatic Gas Regulator System Using Arduino

L Dewi* and Y Somantri

Department of Electrical Engineering Education, Universitas Pendidikan Indonesia, Bandung, Indonesia

*laksmitadewi@student.upi.edu

Abstract. Most of LPG explosions are caused by undetected gas leakage in the pre-detection condition. So that, LPG detection system is needed. The purpose of this system is to detect gas leakage, neutralize it, and prevent the explosion. Gas leakage could happen due to improper regulator installation or the hose is broken. This detection should not work in just one location because gas can leak at the gas regulator and its hose. Therefore, Wireless Sensor Network (WSN) is one of the methods that suitable for detecting gas leakage in the wider area. This method uses two or more gas sensors to detect leakage in two or more locations around the gas tube and its distribution line. WSN system works based on gas sensor MQ-6 and wireless module Bluetooth HC-05. Explosion prevention system works based on alarm/buzzer, exhaust fan, and automatic gas regulator. If the gas leaks, the sensor will send its data wirelessly to Arduino. Then, explosion prevention system will be activated. The system will turn the alarm/buzzer on, automatically releases gas regulator, and neutralizes the air with the exhaust fan. Both systems will be fully controlled by Arduino platform.

1. Introduction

There are still many cases of LPG explosion that happen in the society. Despite, the number of it is not as many as formerly when the first LPG is applied in massive. However, it frequently causes fire forest. Forest fires may cause some relevant losses towards residential structures, infrastructures, industrial facilities, farms, and vegetation, and they are a relevant threat to human life [1].

Almost all of the explosion happen caused by the undetected leakage. In the beginning, LPG has no scent. So it will make LPG hard to detect. Be aware of that, Pertamina added mercaptans gas to make it has a unique and nose piercing smell [2]. Then the LPG will be easier to detect. But sometimes the leakage occurs when there is nobody home. If that happens, gas will spread widely with no warning. This is so risky and the explosion will happen in anytime.

The leakage can occur with some factors. In some cases, it happens because of incorrect regulator installation [3], the tube rubber is worn out, brittle hose, the tube is already obsolete [3], and many others. In addition, BSN present the comprehensive data about under standard gas stove. They are 20 percent of the regulator, 50 percent of the gas stove, 66 percent of valve tube, and 100 percent of hose that out of standard[3]. From all that factors, most of it occurs around the tube mouth and the hose. Because in the tube mouth, gas can slip in and out easily. But, the leakage can also occur around the connection between the hose and the stove. It will happen when the hose is obsolete and/or the connector is gradually loose.

Based on that background, desire to create explosion preventing action appear. This action needs a system that detects early leakage. Weigh the leakage factors can occur about the tube and the hose, then detection will be done in two areas. In addition, the system needs quick action to release the regulator to the tube. So, it will use WSN (Wireless Sensor Network) and automatic regulator.

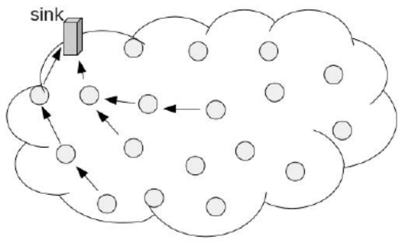

Figure 1. Wireless Sensor Network System [2].

WSN [2] is a wireless ad-hoc multi-hop network which consists wireless sensor node and sink as the main data receiver like figure 1. Environmental information collected by sensor nodes is routed from the ad hoc network to the sink node, where the data can be analyzed and aggregated [4].

From the background explanation above, then we can propose this research goal is to create a tool. A tool for wireless detection and prevention system. The research is still underway when this paper is made. This research hopefully will answer the problems of explosion prevention system concept which still have a gap. Also hopefully this will help leakage detection problems.

2. Methods

2.1. System Design

The system is divided into two. Main system and supporting system. The main system consists of the Arduino Uno [5], gas sensor MQ-6 [6], Bluetooth HC-05 [7], buzzer, LED, LCD, exhaust fan, and synchronous motor [8]. This system is the main system for the research. In addition, the supporting system consists of the Arduino Nano [9] which will operate the MQ-6 and Bluetooth HC-05. The system will be placed separately with the main system and connected wirelessly to it. WSN will connect detection in two areas. The first sensor connects straightaway to the main system and placed in the gas tube. The second sensor connects to the second system and placed near the stove and the hose connection.

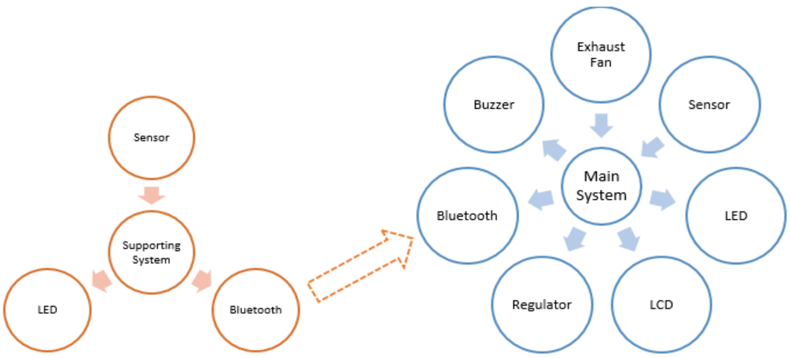

Figure 2. Hardware Design.

2.2. Hardware Design

The research uses some hardware. Arduino Uno and Nano are used as the microcontroller for both systems. The gas sensor is MQ-6. MQ-6 has high sensitivity to natural gas and LPG compositions like Propane and Butane [10]. MQ-6 can detect 300 – 10.000 ppm of gas concentration. Bluetooth HC-05 is used as the wireless module that connects both systems. HC-05 has 3 Mbps data rate [7] and its range approximately 10 m. The warning system is provided by the buzzer and the LED. The LCD displays the level of gas leakage. The exhaust fan can neutralize the air when the leakage occurs. Meanwhile, the automated regulator is driven by one phase synchronous motor. The synchronous motor is usually used as rotary on the fan.

Hardware design for the main system is designed with a plastic container. The first container will hang on the gas tube. The supporting system that placed near the hose is also designed with a plastic container. But, this two container have different plastic materials. The second container can be placed anywhere because of its flexibility. It is flexible because it doesn't need wire to be connected to the first container. The second container can be placed 10 m maximum range from the first container.

The main system uses AC as the power supply. Because there are so many components that are used, AC is chosen to replace the battery. However, the supporting system still uses the battery since it just consists of Arduino Nano, HC-05, MQ-6, and LED. The battery even uses to support its flexibility.

2.3. Software Design

Software design is all the work out of programming design. How it makes a system that works based on the required instructions. Because Arduino is used, then the programming design is fully done with Arduino IDE.

```
void setup() {
  digitalWrite(FAN, HIGH);
  digitalWrite(REG, HIGH);

  pinMode(LED_YELLOW, OUTPUT);
  pinMode(LED_GREEN, OUTPUT);
  pinMode(LED_RED, OUTPUT);
  pinMode(sensor, INPUT);
  pinMode(BUZZER, OUTPUT);
  pinMode(FAN, OUTPUT);
  pinMode(REG, OUTPUT);
  pinMode(limswitch, INPUT);

  lcd.setBacklightPin(BACKLIGHT_PIN,POSITIVE);
  lcd.setBacklight(HIGH);
  lcd.begin(16, 2);
  digitalWrite(LED_YELLOW, HIGH);
  tone(BUZZER, 2500);
  delay(100);
  noTone(BUZZER);
  delay(100);
  tone(BUZZER, 2500);
  delay(100);
  noTone(BUZZER);
  delay(100);
```

Figure 3. Arduino Ide Program.

2.4. Simulation

The first thing to do in simulation process is sensor calibrating. Specific tools for calibrating the sensor will cost so much. Also, it will take too much time and exact knowledge will be needed. But, if the calibration is done with the proper test, it will show as precise as it should be. So the easier way to calibrate the sensor is using a simple Arduino program. The calibration program is provided by one of the online electronics design platforms. Calibration should be done in 1000 ppm of LPG. So we could get the value of MQ-6 reading.

```
Calibrating...
LPG = 0ppm
CH4 = 0ppm
Ro = 60.85kohm
MQ = 32.00
```

Figure 4. MQ-6 Calibration.

According to the data that released by NIOSH [3], the threshold for LPG is 2000 ppm (10% LEL). LEL is an abbreviation from Lowest Explosion Limit [11]. There are two explosion mechanisms that need to be considered when evaluating the inflammable gas incident, they are detonation and deflagration. Detonation is shocked reaction where the fire moves faster at supersonic speed (faster than sound). While deflagration is where the fire moves at subsonic speed [3].

After sensor calibration is done, the simulation can be started. In this simulation, the gas match is used for giving a gas leakage simulation around the sensor. The sensor will detect the gas and will send its data to the main system Arduino. Then Arduino will activate all the warning systems, display its data to LCD, turn on the exhaust fan, and release the regulator.

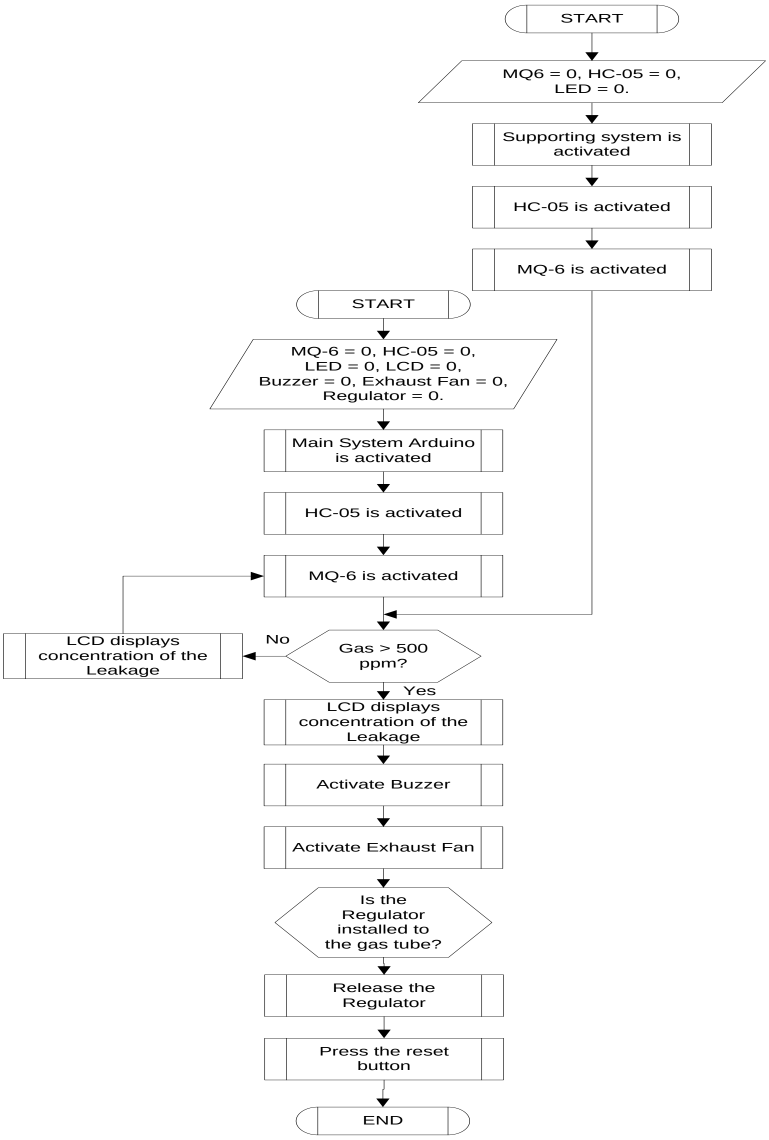

Figure 5. Simulation Flowchart.

3. Results

As the result, this research should detect the leakage around both sensors. Then as the feedback, the system should give the response. The responses are should activate the warning systems, the exhaust fan, and the regulator.

In fact, calibrate the sensor needed a lot of efforts because it was hard to get the value 1000 ppm and the value of Ro precisely. Calibrating the sensor still need a comparison tool. So in this simulation, MQ-6 would be set at the value of 300. The buzzer will sound when the sensor reaches the lowest limit 300 based on the value presented by MQ-6.

Arduino state three conditions. They are Initialize, Stand-By, and On Fire. First, Initialize state is the condition where Arduino recently turns on. It shows the opening message and the opening sound. Second, Stand-By state is the condition where the sensors start sensing. The condition is marked by the blinked green LED. In this condition, the sensors sense over and over again. Third, On Fire state is the condition when the sensor is detecting gas leakage. In this condition, the buzzer is keep ringing, the red LED and the exhaust fan are on, and also, the regulator is released by the system. The table below is showing all the data from this research. The table is showed according to the component's response based on Arduino's condition.

Table 1. Supporting System.

Arduino	MQ-6	Yellow LED	Green LED	Red LED	HC-05
Initialize	-	On	Off	Off	-
Stand By	<300	Off	On	Off	-
On Fire	≥300	Off	Off	On	-

Table 2. Main System.

Arduino	**MQ-6**	**Yellow LED**	**Green LED**	**Red LED**	**Buzzer**	**LCD**	**Exhaust Fan**	**Regulator**	**HC-05**
Initialize	-	On	Off	Off	On	==WELCOME!== SISTEM ACTIVATED	Off	Off	-
Stand By	<300	Off	Blink	Off	Off	Kadar LPG: … Kadar LPG Aman	Off	Off	-
On Fire	≥300	Off	Off	On	On	Kadar LPG: … Bocor Pak Bu!!	On	On	-

4. Discussion

Unfortunately, based on both tables, the wireless system is still not working yet because it should need some troubleshooting. The problem is the Bluetooth module couldn't communicate each other even they are connected. This is still a homework job for this research. One more thing to be considered from this research, the DC supply for the supporting system needs to be more assessed because it could be out of power at any time. In this case, a battery 9V can only power supporting system up during 15 hours approximately.

5. Conclusions

The conclusions that can be drawn from this research are:

- Calibration process still needs comparison process.
- MQ-6 has high sensitivity to the contents of LPG.
- All components of the main system have a successful response except the Bluetooth module.
- The main system and the supporting system are ready to use.
- Need some wires to connect the supporting system to the main system since the Bluetooth module didn't work yet.

The research is still needed evaluation to be a successful research. It has some problems and needs some repair. But, the system is ready to be analyzed and continued by anyone who has interest in solving matters about this LPG explosion.

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