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Design of Microcontroller Based System to Prevent Wildfire due to LPG Leakage

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ABSTRACT: Gas leakage of the Liquefied Petroleum Gas (LPG) cylinder is possible to occur any time due to improper function of parts of either LPG cylinder or LPG pressure regulator. LPG leakage causes wildfire if not handled immediately. Objective of the research is to solve the problem by designing the microcontroller based system to prevent wildfire due to gas leakage of LPG cylinder and send notification about LPG leakage to homeowner's smartphone. By design, the ESP32 microcontroller measures LPG leakage intensity via MQ-6 sensor. If LPG leakage is more than 100 ppm, then ESP32 microcontroller drives the servo motor to release the gas pressure regulator against the LPG cylinder. It is the effort to stop LPG leakage. After that, ESP32 microcontroller turns-on the alarm buzzer, displays a message on the LCD, turns-on the exhaust fan removing LPG leakage out from room, and sends WhatsApp notification to homeowner's smartphone. This system is also equipped with the infrared obstacle avoidance sensor to detect whether the exhaust fan turns or not. If the exhaust fan does not turn, the microcontroller turns-on the alarm buzzer and sends WhatsApp notifications.

The test result shows that the system operates properly as designed. Moreover, system has 1.47% of average error of LPG gas concentration reading against the reading by standard measuring equipment.

KEYWORDS: LPG leakage, Microcontroller, ESP32, MQ-6 gas sensor, Servo motor, WhatsApp

I. INTRODUCTION

People commonly uses Liquefied Petroleum Gas (LPG) as fuel gas for cooking, vehicle, and heating equipment. LPG is a flammable gas which contains mixture of propane, propylene, butylene, isobutene, n-butane, and odorant such as tetrahydrothiophene (thiophane) or amyl mercaptan [1]. LPG cylinder contains high pressure gas so it needs gas pressure regulator to use. In its operation, proper fitting and locking of gas pressure regulator on the outlet of LPG cylinder will make the gas to flow out, otherwise gas does not flow out.



Fig. 1: Gas Pressure Regulator Fitted on the Outlet of LPG Cylinder

On the other hand, LPG leakage is possible to occur any time due to improper function of parts, such as rubber seal inside of the LPG cylinder outlet, hose, and mechanical parts of gas pressure regulator. LPG leakage is potential to cause wildfire if not handled immediately.

However, people cannot check every time whether the LPG leakage occurs because they are busy and not always at home where the LPG leakage occurs. Moreover, people are often late to prevent wildfire when LPG leakage occurs.

Objective of the research is to solve the problem by designing the microcontroller based system to prevent wildfire due to LPG leakage and send notification about LPG leakage to the homeowner's smartphone. Therefore, the system must have main capabilities to detect LPG leakage, to release automatically the gas pressure regulator against LPG cylinder if LPG leakage occurs, to remove LPG leakage out from room, and to send notification to homeowner's smartphone via internet. The research contributes to save human life and proprietary by preventing wildfire due to LPG leakage.

II. RELATED WORK

S. Natarajan, et al. [2] proposed the system for LPG leakage detection and prevention. They used LPG sensor (MQ-6) to detect the LPG leakage. If LPG leakage occurs, the microcontroller (Arduino) based system turns-on alarm buzzer and sends notification via SMS (Short Message Service) to the owner by using GSM900 module.

Identical with the research above, M. S. Hassibuan, et al. [3] proposed intelligent LPG gas leakage detection tool with SMS notification. They used LPG sensor (MQ-2) to detect LPG leakage and used SIM800 module to deliver message via SMS.

A. Manhas, et al. [4] proposed system for LPG leakage detection using IoT. They used LPG sensor (MQ-5) to detect the LPG leakage. If LPG leakage occurs, the microcontroller (NodeMCU) based system turns-on alarm buzzer and sends notification to user's Android smartphone via internet. It is possible because NodeMCU has Wi-Fi interface.

Tamil Selvi, et al. [5] proposed the system for LPG leakage detection and monitor. They used LPG sensor (MQ-6) to detect the LPG leakage. If LPG leakage occurs, the microcontroller (Node MCU) based system turns-on alarm buzzer and sends notification to user's Android smartphone via internet by using Blynk application software. The system also reports the remaining weight of gas content inside of LPG cylinder because of having load cell to measure.

P. Jayaswal, et al. [6] proposed the IOT based smart LPG leakage detection system using microcontroller (Arduino). If LPG leakage occurs, the microcontroller (Arduino) based system turns-on alarm buzzer, closes the gas supplying valve and sends notification to user's Android smartphone via internet by Google. The system uses LPG sensor (MQ-5) to detect LPG leakage and also utilizes fan to remove LPG leakage out from room.

Nema R. Shahapurkar, et al. [7] proposed the system for LPG leakage detection and control for safety. If LPG leakage occurs, the ATmega 328 microcontroller based system turns-on alarm buzzer, turns-off the LPG pressure regulator by using stepper motor, and sends notification to user's phone via SMS by using GSM module. The system uses LPG sensor (MQ-6) to detect LPG leakage and also utilizes exhaust fan to remove LPG leakage out from room.

Shreya P and Raghavendra R [8] proposed the efficient model for gas leakage detection using IoT. They used LPG sensor (MQ-6) and microcontroller (NodeMCU) as main processing unit. System displays LPG leakage concentration on LCD. If LPG leakage exceeds the threshold, microcontroller turns-on alarm buzzer, turns-off the knob of LPG pressure regulator by using servo motor, and sends notification via SMS to user's phone.

III. METHODOLOGY

To achieve the research objective, step of research consists of system design, implementation, and testing. Moreover, troubleshooting and improvement are conducted if improper function of the system occurs.

The following Figure-2 shows the miniature design of microcontroller based system to prevent wildfire due to LPG leakage. Meanwhile, block diagram of the system is shown in Figure-3. It shows that the system devices include control unit (microcontroller ESP32) having Wi-Fi port, LPG leakage sensor (MQ-6), servo motor connected to the turn lock of the LPG pressure regulator, alarm buzzer, LCD display, exhaust fan to remove LPG leakage out from room, fan rotation detector, wireless router, and AC-to-DC power supply. Besides, Figure-4 shows interconnection of servo motor and the turn lock of LPG pressure regulator.

In its operation, system will release automatically the gas pressure regulator against LPG cylinder if LPG leakage occurs. This automatic action will make LPG does not flow out from LPG cylinder any more so LPG leakage stops. After that, system turns-on alarm buzzer, displays message on LCD, and sends notification about LPG leakage to homeowner's smartphone via internet.

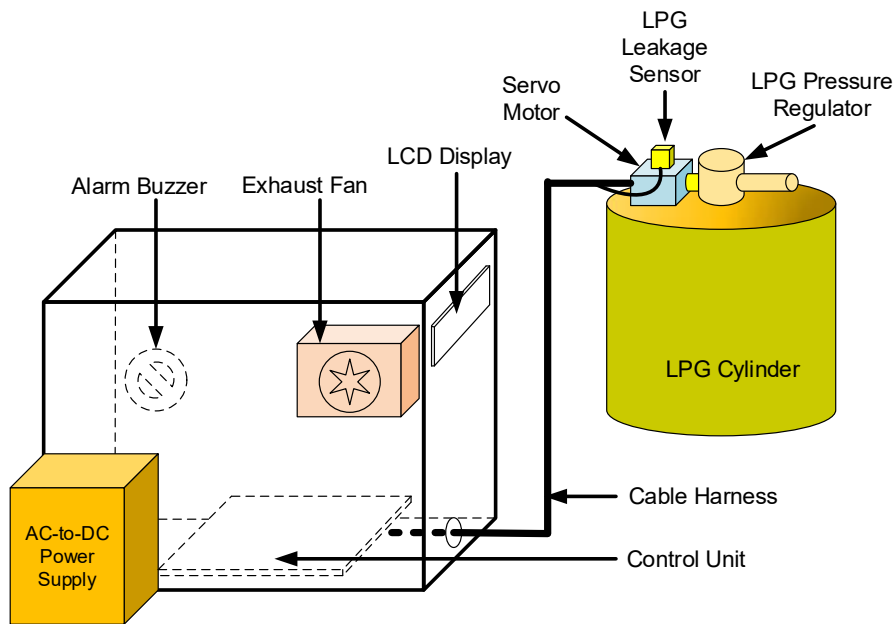


Fig. 2: Miniature Design of Microcontroller Based System to Prevent Wildfire due to LPG Leakage.

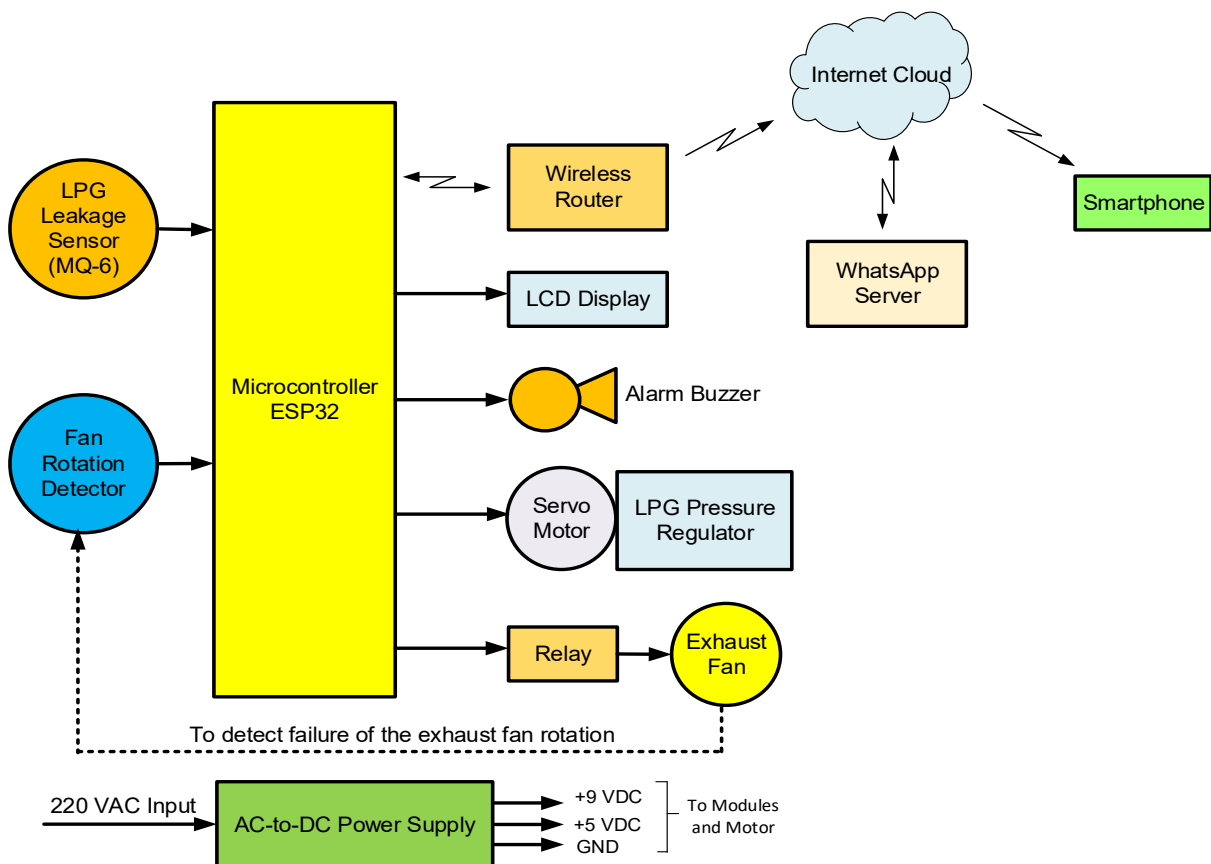


Fig. 3: Block Diagram of the Microcontroller Based System to Prevent Wildfire due to LPG Leakage

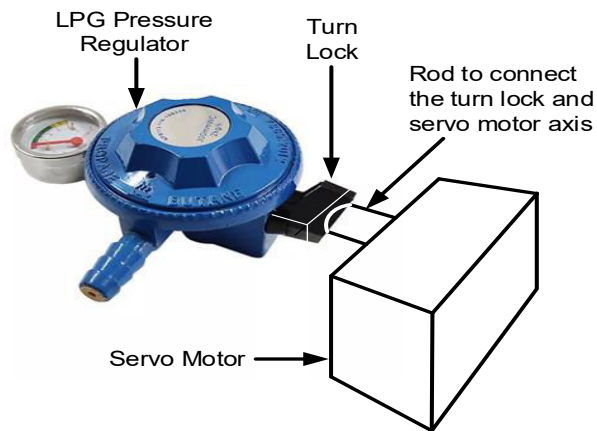


Fig. 4: Interconnection of Servo Motor and the Turn Lock of LPG Pressure Regulator

By design, the ESP32 microcontroller measures LPG leakage concentration via MQ-6 sensor. If LPG leakage is more than 100 ppm, then ESP32 microcontroller drives the servo motor (TD8120MG) to release the gas pressure regulator against the LPG cylinder. After that, ESP32 microcontroller turns-on the alarm buzzer, displays a message on the LCD, turns-on the exhaust fan removing LPG leakage out from room, and sends WhatsApp notification to homeowner's smartphone via internet. This system also uses the infrared obstacle avoidance sensor (FC-51) to detect whether the exhaust fan turns or not. If the exhaust fan does not turn, the microcontroller turns-on the alarm buzzer and sends WhatsApp notifications. The following Figure-5 shows wiring diagram of the system.

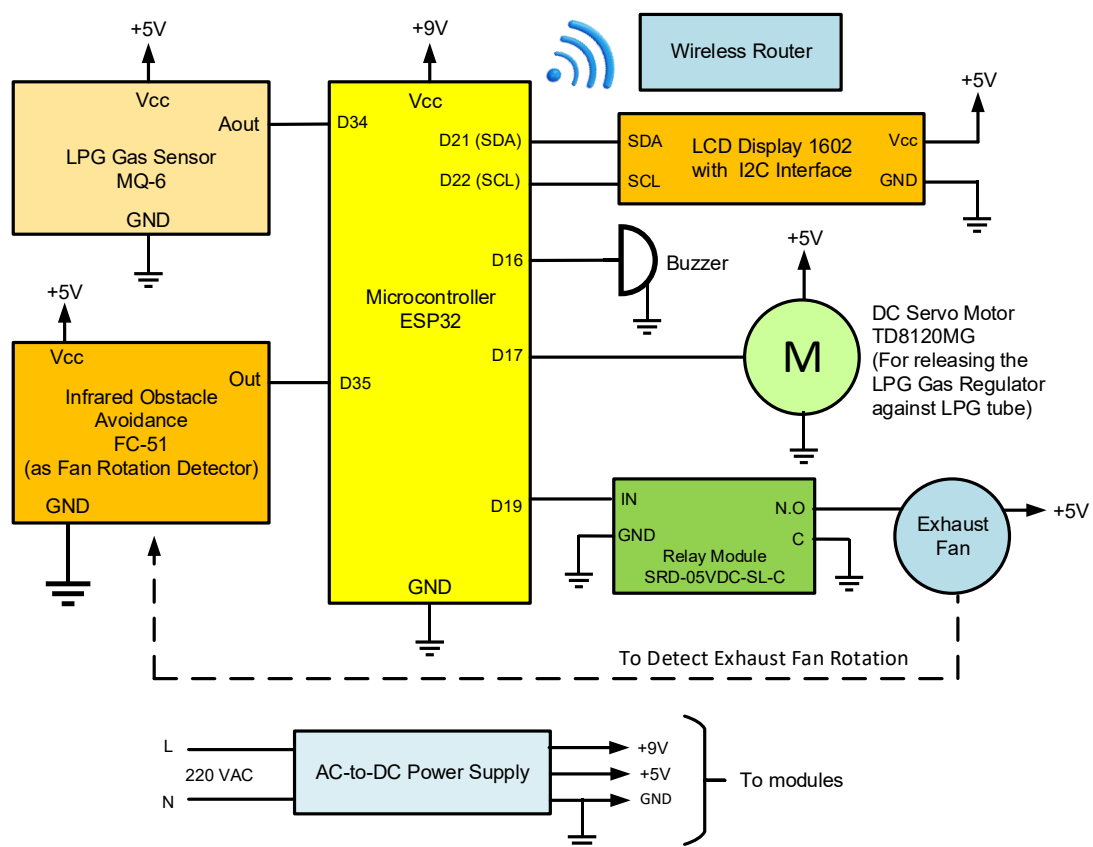


Fig. 5: Wiring Diagram of the Microcontroller Based System to Prevent Wildfire due to LPG Leakage

As described before, this system utilizes ESP32 microcontroller which works by using the dedicated software. The following Figure-6 shows the flowchart of which software using Arduino programming language refers.

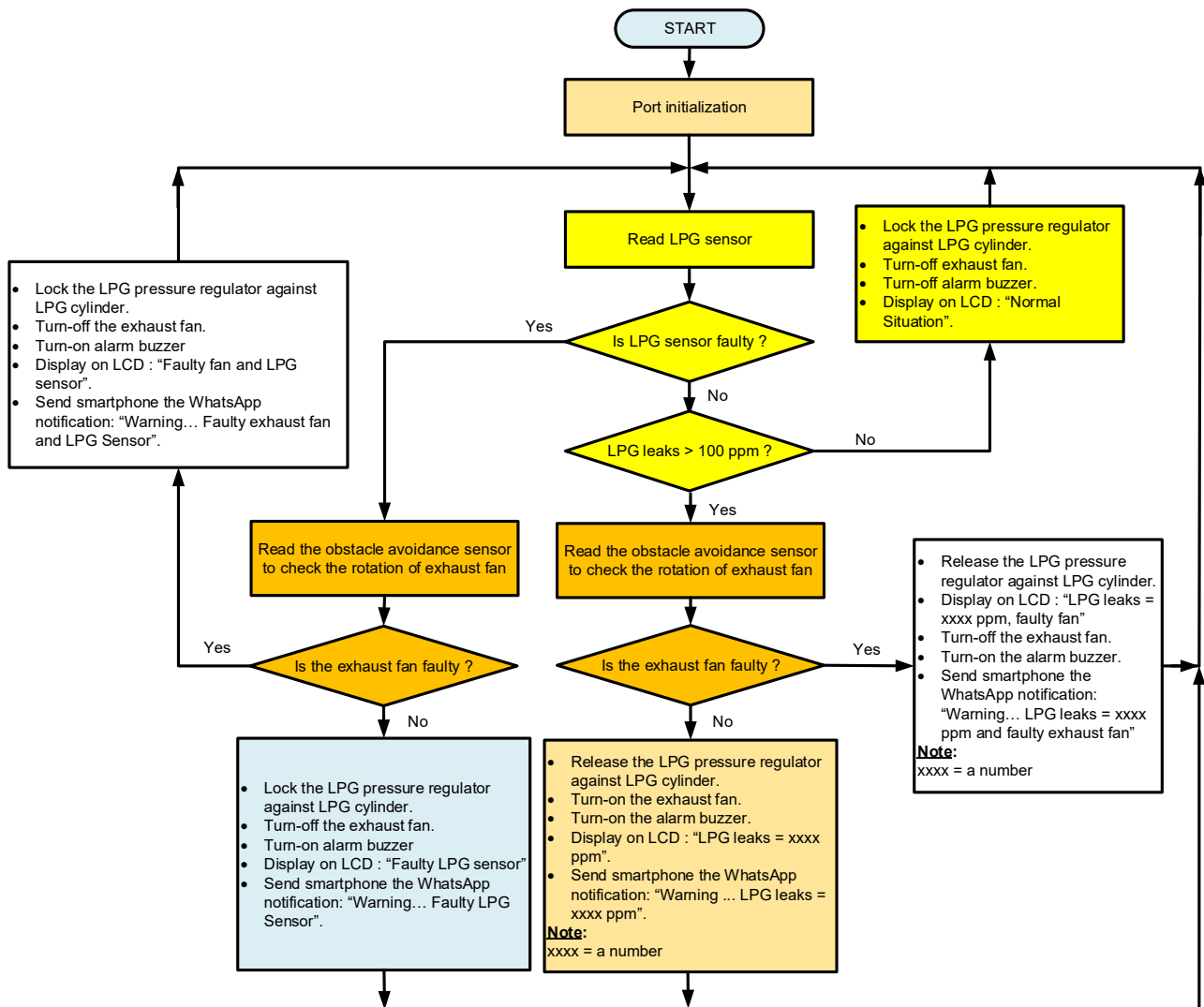


Fig. 6: Software Flowchart of Microcontroller Based System to Prevent Wildfire due to LPG Leakage

As shown in Figure-6, microcontroller starts to read the LPG sensor. If LPG leakage is more than 100 ppm and exhaust fan is not faulty then microcontroller releases the LPG pressure regulator against LPG cylinder, turns-on exhaust fan to remove LPG leakage out from room, turns-on the alarm buzzer, displays the concentration of LPG leakage on LCD, and sends WhatsApp notification about LPG leakage to user’s smartphone.

III. EXPERIMENTAL RESULTS

A. Results of Design Implementation

The following Figure-7 shows model of the microcontroller based system to prevent wildfire due to LPG leakage as the result of design implementation.

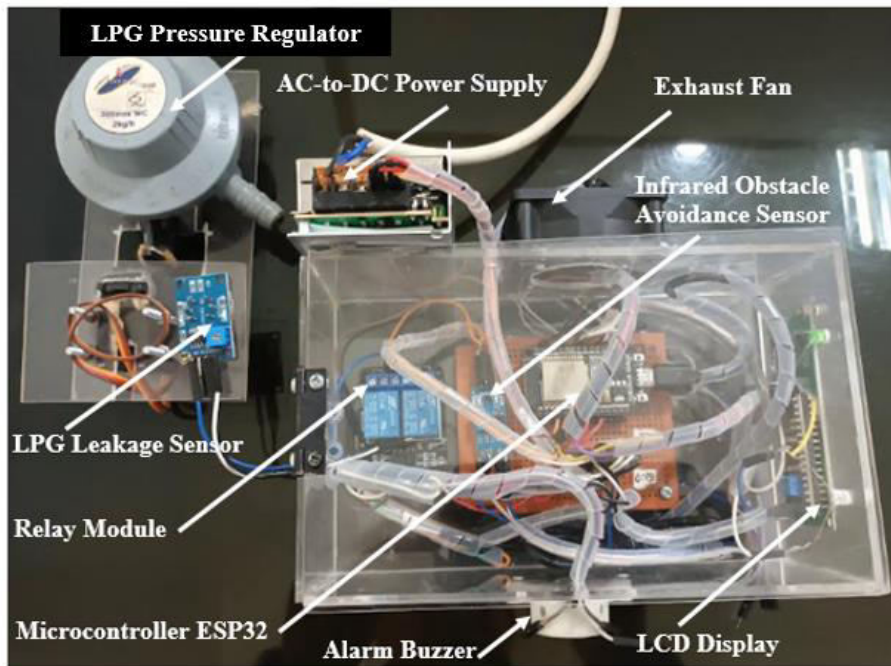


Fig. 7: Model of Microcontroller Based System to Prevent Wildfire due to LPG Leakage

As shown in Figure-7, LPG leakage sensor is located near the LPG pressure regulator fitted on the outlet of LPG cylinder. Therefore, LPG leakage, even small leakage, can be detected easily.

The following Figure-8 shows mechanism to release the LPG pressure regulator by servo motor. To release the LPG pressure regulator, microcontroller ESP32 drives servo motor to turn its axis by 90°.

Meanwhile, Figure-10 shows the integration of the system including small LPG cylinder ,LPG pressure regulator, and the control unit.

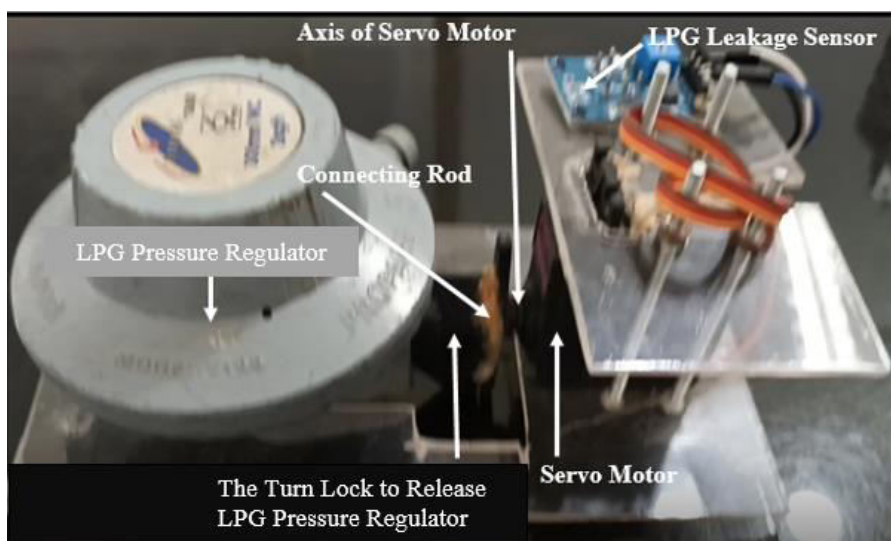


Fig. 8: Mechanism to Release LPG Pressure Regulator by Servo Motor



Fig. 9: System Integration

B. Functional Test Result

The following Table-1 shows the result of functional test of the system for some test input.

Tabel-1: System Functional Test Result

No.	Test Input	Actual Response of System (Based on Observation)	Remark
1	<ul style="list-style-type: none"> Concentration of LPG = 1 ppm - 100 ppm (= Categorized as no LPG leakage) Exhaust fan is not faulty. 	<ul style="list-style-type: none"> LPG pressure regulator is locked against LPG cylinder. Exhaust fan turns-off. Alarm buzzer turns-off. LCD displays “Normal Situation”. 	<ul style="list-style-type: none"> The actual system response complies as designed.
2	<ul style="list-style-type: none"> Concentration of LPG = 1 ppm - 100 ppm (= Categorized as no LPG leakage) Exhaust fan is faulty. 	<ul style="list-style-type: none"> LPG pressure regulator is locked against LPG cylinder. Exhaust fan turns-off. Alarm buzzer turns-on. LCD displays the message: “Faulty fan”. Smartphone receives WhatsApp notification: “Warning... Faulty exhaust fan”. 	<ul style="list-style-type: none"> The actual system response complies as designed.
3	<ul style="list-style-type: none"> Concentration of LPG is more than 100 ppm (= Categorized as LPG leakage). Exhaust fan is not faulty. 	<ul style="list-style-type: none"> LPG pressure regulator loose against LPG cylinder. LCD displays the message: “LPG leaks = xxxx ppm” Exhaust fan turns-on. Alarm buzzer turns-on. Smartphone receives WhatsApp notification: “Warning... LPG leaks = xxxx ppm”. <p>Note: xxxx = a number.</p>	<ul style="list-style-type: none"> The actual system response complies as designed.

No.	Test Input	Actual Response of System (Based on Observation)	Remark
4	<ul style="list-style-type: none"> Concentration of LPG is more than 100 ppm (= Categorized as LPG leakage). Exhaust fan is faulty. 	<ul style="list-style-type: none"> LPG pressure regulator loose against LPG cylinder. LCD displays the message: "LPG leaks = xxxx ppm, faulty fan" Exhaust fan turns-off. Alarm buzzer turns-on. Smartphone receives WhatsApp notification: "Warning... LPG leaks = xxxx ppm and faulty exhaust fan". <p>Note: xxxx = a number.</p>	<ul style="list-style-type: none"> The actual system response complies as designed.
5	<ul style="list-style-type: none"> LPG leakage = 0 ppm (= Indicates that LPG leakage sensor is faulty). Exhaust fan is not faulty. 	<ul style="list-style-type: none"> LPG pressure regulator is locked against LPG cylinder. Exhaust fan turns-off. Alarm buzzer turns-on. LCD displays the message: "Faulty LPG sensor". Smartphone receives WhatsApp notification: "Warning... Faulty LPG sensor" 	<ul style="list-style-type: none"> The actual system response complies as designed.
6	<ul style="list-style-type: none"> LPG leakage = 0 ppm (= Indicates that LPG leakage sensor is faulty). Exhaust fan is faulty. 	<ul style="list-style-type: none"> LPG pressure regulator is locked against LPG cylinder. Exhaust fan turns-off. Alarm buzzer turns-on. LCD displays the message: "Faulty fan and LPG sensor". Smartphone receives WhatsApp notification: "Warning... Faulty fan and LPG sensor" 	<ul style="list-style-type: none"> The actual system response complies as designed.

Table-1 shows that the actual system response for each test input always complies as designed. It means that all parts of the system works properly and the software algorithm is also correct.

C. Accuracy Test Result of LPG Concentration Reading

Accuracy test of LPG concentration reading compares the concentration reading by the system with LPG sensor (MQ-6) against the concentration reading by standard measuring equipment (= LPG gas detector, Brand: Kerui, Type Number: GD13). Calculation of error percentage of LPG concentration reading refers to the following formula:

$$\text{Error (\%)} = \left| \frac{\text{Reading result by the system} - \text{Reading result by standard measuring equipment}}{\text{Reading result by standard measuring equipment}} \times 100\% \right|$$

The following Tabel-2 shows accuracy test result of LPG concentration reading.

Tabel 2: Accuracy Test Result of LPG Concentration Reading

No.	LPG Concentration Reading by Standard Equipment (ppm)	LPG Concentration Reading by System with MQ-6 Sensor (ppm)	Error (%)
1	65	63	3.08
2	72	70	2.77
3	77	75	2.59
4	86	84	2.32
5	106	100	5.66
6	125	122	2.40
7	158	155	1.89
8	204	199	2.45
9	343	340	0.87
10	368	366	0.54
11	473	464	1.90
12	482	485	0.62
13	497	490	1.41
14	582	574	1.37
15	623	627	0.67
16	642	638	0.62
17	655	659	0.61
18	678	665	3.39
19	692	684	1.15
20	708	713	0.71
21	746	737	1.21
22	761	765	0.52
23	832	841	1.08
24	868	860	0.92
25	926	933	0.75
26	961	957	0.41
27	1124	1135	0.97
28	1168	1162	0.51
29	1240	1244	0.32
30	1277	1271	0.46
Average error (%)			1.47

Table-2 shows that the system with LPG sensor (MQ-6) provides average error of LPG concentration reading by 1.47 % against the reading by standard measuring equipment. It also means that the proposed system has 98.53% of accuracy level of LPG concentration reading against the reading by standard measuring equipment. The error of LPG concentration reading occurs because MQ-6 sensor performance is affected by operating temperature and humidity.



IV. CONCLUSION

Referring to the test result and analysis, the research concludes as follows:

1. The proposed system succeeds to detect LPG leakage, to prevent wildfire due to LPG leakage by releasing gas pressure regulator against LPG cylinder, and to send WhatsApp notification about LPG leakage via internet.
2. Average error of LPG concentration reading is 1.47% against the reading by standard measuring equipment.

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