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The experimental study of the flammable gas detecting system for the biogas engine and filler

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Abstract. Biogas has been utilized in many applications from direct and internal combustion because methane is its main flammable component and it can be produced by waste in household and industrial levels. This work focused on the experimental study of the in-house flammable gas detecting system for two biogas utilizing applications; the biogas engine and filler. For the application safety operations, the in-house system was designed to detect the biogas leakages and to turn off the biogas applications. The in-house system was fabricated on Arduino board and tested its functions in seven different butane gas releasing positions and three different biogas releasing positions. The experimental study showed that the system could detect butane in different distances within different periods of time. The system could turn off the biogas applications when it detected the butane gas at even the longest distance of 30 centimeters in an average time of 4.52 seconds. The system could also detect biogas and could turn off the biogas engine and filler in 2.33 seconds according to the set limited valve. The detecting system revealed its potential to be a safety feature for biogas utilizing applications; especially the biogas engine and filler, with acceptable price and reliable works.

1. Introduction

Biogas has emerged as one of promising fuel types because it could be produced locally in many levels. With hot and humid weather in Southeast Asian, biogas can be produced widely. Biogas has been utilized mainly in a household application; i.e. combustion fuel for the cooking purpose, it can replace Liquid Petroleum Gas (LPG). Methane as one main component of biogas is flammable and methane is one of greenhouse gas, the biogas utilization can help people reducing amount of methane released into atmosphere. Other biogas utilizations have been investigated and developed, one of them is biogas engines which can be developed from gasoline and diesel engines with single or multi pistons. In engine modifications for household and industrial utilizations, the engine efficiency and safety are significantly concerned for users and developers. In Thailand, many accidents were reported which were related to biogas leakages, human errors and malfunction equipment in biogas applications [1,2] and many Thai government departments have presented and informed about biogas safety continuously such as Department of Alternative Energy Development and Efficiency [3] and Department of Industrial Works [4], Thailand.

Sinworn et al. [5] designed and fabricated a smoke and LPG leakage detecting system coupled with an emergency warning system. When the detecting system detected the LPG, an alarm was on and another signal was sent through a cellphone network to turn on a ventilation system to ventilate LPG out of the leakage area. Their system was operated by using commands on their microcontroller. From their system investigation, they found that their system could detect LPG in the concentration ranged 10000 – 20000 ppm and the emergency warning system via the cell phone network was notified within 11.13 – 16.39 seconds.

Lonkhuntod [6] also designed and fabricated the LPG leakage detecting system coupled with an emergency warning system by using commands on their microcontroller. When the detecting system could detect the LPG, the system sent out signals via output port to alarm users by siren sound and to turn on a ventilating system. The detecting system was installed with a domestic detection sensor (Methane detector, FG100S, KIMO) and LPG leakages inside a kitchen was focused and investigated in his study. He set the 1000 ppm of LPG as the lowest LPG concentration limit to trick the system to send SMS thru the cellphone network while an alarm was on and the ventilating system was working during LPG concentrations were higher than the lowest concentration limit. He concluded that his system was workable with acceptable conditions but no information about working time was presented in this work.

Ditsakorn [7] published his work on a website to show his work; an LPG leakage detecting system coupled with an emergency warning system. He applied MATLAB Simulink to operate his integrated system which was driven by 5 VDC current. He suggested that the sensors in the system should be calibrated or validated with standard concentration gas.

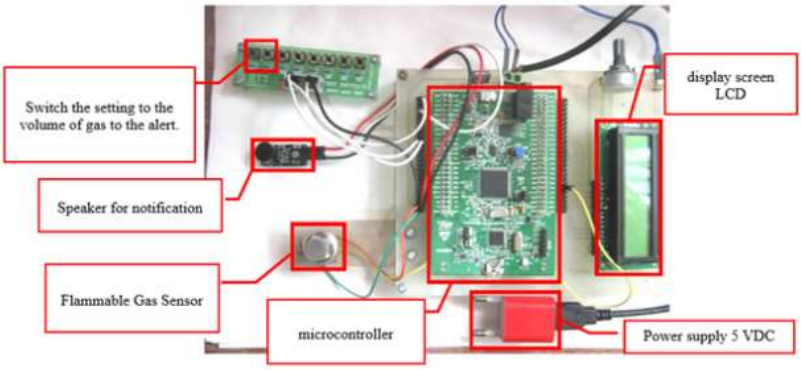

Figure 1. Gas detector from Ditsakorn's work [7].

Wiwatwanichwong et al. [8] experimentally investigated their LPG leakage detecting system coupled with an emergency warning system; they sent signals thru the GSM network. They selected 4 flammable substances to test their system; LPG compressed in a can, Gasohol 95 (5% Ethanol and 95% Gasoline), Butane from a lighter and Ethanol solution (70% Ethanol and 30% water). They found that their system could detect leakage gas in order of the first three mentioned flammable substances; excepting the Ethanol solution. In this work, the released gas position in the experimental investigations was fixed at 15 cm, thus the system could detect and alarm the released gas. They also presented gas concentrations detected by their system relating with releasing times.

Jettarach [9] introduced his biogas filler prototype with an unwanted-gas filter and safety system (Figure 2) which can be used to fill the clean biogas inside household gas tanks, his primary safety system consisted of a pressure switch to control minimum and maximum pressure levels and pressure gage. The prototype was experimentally investigated to fill biogas into the tank between the minimum pressure at 20 psig and the maximum pressure at 100 psig, the pressure switch sent electric signal to stop compressor operation when the biogas pressures in the prototype were under and over the controlled values. The biogas filter was also tested and found that sulphur dioxide contained in biogas was reduced from 162 ppm to 113 ppm. The compressed biogas from the storage tanks was checked for its utilization by using it as fuel in household cooking and as fuel for a small engine with Discharge Pump Fuel Injection (DCP-FI) system but without Engine Control Module (ECM) installed and without ignition system modification, the biogas could be used as fuel in both utilizations. Since biogas is usually used in its production sites, the biogas filler prototype with an unwanted-gas filter and safety system is one way to take biogas and to utilize biogas outside the production sites. This work presented the prototype potential in two main applications with affordable cost.

Pramuanjaroenkij et al. [10] investigated generator transmission systems driven by a hybrid engine which could be fueled with gasoline, LPG or biogas. To study the highest work transmitted from the hybrid engine to the generator; a magnet motor was chosen as the generator in this research because of its few significant characters, three different transmission systems; (1) the pulley (belt system), (2) the screwed shaft and bush and (3) the flanged shaft and bush, connected between the engine and the generator were experimentally investigated. The produced voltages from the generator connected with the biogas engine coupled with the pulley (belt system), screwed shaft and bush and flanged shaft and bush, were 14.84 Volts, 14.10 Volts and 11.82 Volts, respectively, or 99.26 %, 95.21 % and 81.40 % of the average voltages obtained from the generator driven by the gasoline engine. This work emphasized the effects of transmission systems connected between the engine and the generator; proposed transmitter was the screwed shaft and bush and also insisted that biogas engine could drive small households.

Since biogas can be used in many applications; direct biogas combustion in cooking and biogas engines and indirect utilizations by using biogas fillers to storage biogas for later usages, the biogas safety system must be connected with and installed in these applications to detect, alert and reduce biogas damages from biogas leakages. This research was aimed to experimentally investigate an in-house flammable gas detecting system for two biogas utilizing applications; the biogas engine and filler by designing and fabricating the system which could detect the biogas leakages and to turn off the biogas engine and filler. The in-house system performances accroding to different flammable gas leakage distances were also experimental investigated and discussed. The in-house flammable gas detecting system could be revealed for its potential as a necessary biogas utilization accessory.

Figure 2. The biogas filler (Left) from Jettarach [9] and the hybrid engine (Right) from Pramuanjaroenkij et al. [10] which was used to investigate generator transmission systems.

2. Materials and Methods

The Flammable gas detection system was designed for two main purposes; one was to detect flammable gas and another was to turn off biogas applications when a flammable gas concentration detected over the set limitation. Two systems, which were taken into our current attention, were the biogas filler and biogas engine. Firstly, the in-house system was designed to serve its purposed; sensors, controllers and circuits were selected accordingly as shown in Figure 3. Then, all components were assemble according to the design and the in-house gas detection system was calibrated with a gas analyzer; Crowcon trademark, in our laboratory for its readiness to be used in the practical use with the biogas applications. The in-house gas detection system was tested for its response with two types of flammable gas; one was butane and another was biogas from a local biogas producer, Songpeenong

Swine Farm in Sakon Nakhon province, Thailand. In the system experiment with butane, the in-house system was placed in 7 different distances; 0, 2.5, 5, 10, 15, 20 and 30 centimeters from the butane releasing point (Figure 4a), the system was set to detect the flammable gas at 200 units and the system response times to detect the gas concentration at the detected level were recorded and discussed. Since biogas contains methane as its main flammable gas, the in-house gas detector was observed that it could detect the biogas more slowly than its performance in detecting the butane investigation, three different distances in the biogas investigation were 0, 2.5 and 5 centimeters

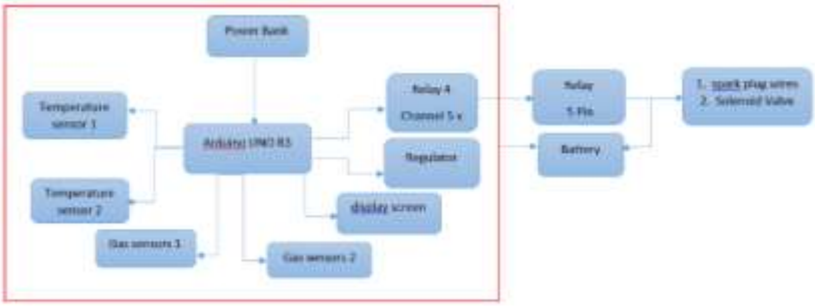

Figure 3. The circuit diagram of the in-house Flammable gas detection system.

(a) (b)

Figure 4. Butane investigation (a) and biogas investigation (b) with the flammable gas detecting system setup.

There was another gas analyser; Portable Biogas Analyzer Crowcon Triple Plus + IR connected and placed next to the in-house flammable gas detection system to measure methane concentration in biogas leakage stream. The Crowcone analyser is a calibrated sensor which can be used to measure methane concentration in a unit of percentage by volume. The gas leakage amount was measured from the detecting system and compared with the amount measured from the analyzer. The system was experimental studied by connecting it with the biogas filler and the hybrid engine to check the system performance, Figure 6 revealed the flammable gas detection system which was connected with the biogas filler to find its function in turning off the filler when the leakage gas level was over the set value at 200 units. Then, the flammable gas detection system was connected with the hybrid engine which could take gasoline, LPG and biogas as its fuel (Figure 7), the system could turn off the engine when the leakage gas level was over the set value at 200 units.

Figure 5. The in-house flammable gas detection system tested with the biogas leakages.

Figure 6. The in-house flammable gas detection system tested its function with the biogas filler.

Figure 7. The in-house flammable gas detection system tested its function with the biogas engine.

3. Results and Discussion

After the final circuit design was selected, all components were connected as the design according to the design purposes and the in-house flammable gas detecting system was fabricated as shown in Figure 8. The system consists of two flammable gas detecting sensors, one monitor, one regulator, one Arduino controller, two relays and one power supply connector. The flammable gas sensor could detect not only flammable gas concentration but also temperature since common combustion occurred by three parts as heat, fuel and oxygen, the in-house system was designed to detect two of three parts in the combustion. Two sensors of the in-house system could be placed to detect fuel leakage in two different places, more chances to detect the leakage and heat. The monitor displayed flammable gas concentrations and temperatures from both sensors. The in-house system could work when it was supplied by 5V DC electric power such as electric power from portable cellphone power bank. The Arduino controller was chosen because it was easy to program and re-program, Arduino commands were not complicated.

The first set of results was obtained from the butane leakage investigation as set in Figure 4 (a). The butane was released to perform as the butane leakage in 7 different distances; 0, 2.5, 5, 10, 15, 20 and 30 centimeters. The investigations were performed 5 times in each distance and the average detecting times for each distance and the results were reported as shown in Table 1. The fastest detection occurred at the closest sensor distance between the sensor and the butane releasing point or 0 centimeter (next to the releasing point) at 0.65 second and the slowest detection occurred when the sensor was placed in the farthest distance from the butane releasing point or 30 centimeters, the in-house system took 4.52 seconds to detect the butane.

Figure 8. Butane investigation.

Table 1. Experimental results of the flammable gas detection system in the butane leakage investigation at atmospheric condition at difference leakage distances.

Distance (cm)	Average response time to the set concentration (s)
0	0.65
2.5	0.73
5	0.90
10	1.28
15	1.89
20	2.57
30	4.52

When the in-house flammable gas detecting system was firstly tested for its performance with the common flammable gas or the butane. The second investigation was the biogas leakages in three different distances between the sensor and the leakage point (0, 2.5 and 5 cm), from the first few observations, the flammable gas concentration or methane concentration in biogas was quite lower than the butane and the in-house system took time to response to the biogas. The in-house system responded to the flammable gas in the biogas as it responded to the butane. Among 0, 2.5 and 5 centimeters in distances (Table 2), the fastest time to show the measured value was 2.33 seconds, the response time in the second investigation was quite slower than that of the first investigation. At these distances, the Crowcon gas analyzer could also detect different methane concentrations, the analyzer detected 5.33 % CH_4 by volume at 2.33 seconds.

Table 2. Experimental results of the flammable gas detection system in the biogas leakage investigation at atmospheric condition at difference leakage distances

Distance (cm)	Average detecting time (s)	Average methane gas concentration detected by the gas analyser (% by vol.)
0	2.33	5.33
2.5	14.33	17.55
5	21.00	27.00

Two last investigations were to evaluate the function of the in-house system to turn off two biogas applications when the leakage gas concentrations were over the set values. The biogas filler to store biogas for movable applications and remote areas from biogas producers and the biogas engine which could also take gasoline and LPG as its fuel. After the in-house system was set a concentration value to cut the filler and the engine at 200 units, it was connected to the biogas filler at its motor power supply. Biogas was released at the sensor surface to simulate a case where the biogas occurred at the sensor position, the in-house system could turn off the filler motor which was the main driving component of the biogas filler within 2.33 seconds as an average turning-off time, the in-house system could be a workable safety feature for the biogas filler. The biogas engine, so called the hybrid engine, could be used in several purposes such as the engine driving the power generator or driving the vehicle. In the current work, the engine was used as the driving engine for a small vehicle. Then, the in-house system was connected with electrical wire between the power supply battery and igniter, the biogas leakage simulation was repeatedly performed at the closest distance between the sensor and the leakage point or 0 cm. The in-house system could turn off the engine or cut off electric from the battery to the igniter which was the main driving component to make the engine combustion occurred 3 seconds as an average turning-off time, the in-house system could also be a workable safety feature for the biogas engine.

4. Conclusion

Since biogas utilization has been increased continuously, the safety feature for the biogas utilization with common fabrication and low cost investment should be considered. To fabricate the in-house flammable gas system, the system circuit design and all components must be selected accordingly, the component selection was based on available in Thai markets and affordable prices because the system was designed to be the affordable system and easy to replace or maintenance. After the design was selected, all components were assembled, the system was ready to test for its purposes in detecting the flammable gas and turning off the biogas applications if the biogas leakages occurred and the system could detect it. Two main utilisation combine direct and indirect utilisation: the biogas filler as the indirect one and the biogas engine as the direct system. Two fuel gas; butane and biogas, were experimentally used in simulating the flammable gas leakage, when the sensor got closer to the leakage position, the faster the sensor detected the gas concentration. Finally, the in-house system was proved its purpose and it could turn off the biogas filler and the biogas engine within 2.33 seconds. Therefore, the current in-house flammable gas detecting system was the workable system which could be connected with an electric power supply line of any biogas applications. The in-house flammable gas detecting system showed its potential to be the safety feature for any other biogas applications.

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References

[1] Department of Alternative Energy Development and Efficiency (online) Biogas production from waste obtained from animal farms and industries. Retrieved from http://www2.dede.go.th/km_ber/Attach/Biogas-present.pdf. [Accessed on 5 June 2018].
[2] Safety Technology Bureau (online) Biogas, Security Case Study. Retrieved from http://www.asew-expo.com/Portals/0/seminar/Presentation. [Accessed on 23 may 2018].
[3] Department of Alternative Energy Development and Efficiency (online) Biogas safety. Retrieved from http://webkc.dede.go.th/webmax/sites/default/files/Biogas%20Safety_Handbook.pdf. [Accessed on 5 June 2018].
[4] Security monitoring of the biogas system. (online) Retrieved from

http://php.diw.go.th/safety/wp-content/uploads/2015/02/1.biogas.pdf [Accessed on 12 June 2018].

[5] Sinworn S, Korakot S, Pantong P 2014 The development of liquid petroleum gas (LPG) Leak and smoke Detective sensor For Emergency Alarm. Faculty of Science and Technology. Research Report Suan Dusit Rajabhat University Thailand.

[6] Lonkuntos N 2014 The controlling system program using microcontroller with alarm signal to detect LPG in kitchen *Ress. Dev. J. Buriram Rajabhat Univ.* **9** 6 104-112.

[7] Aimagin (online) LPG Gas alam sensor. Retrieved from http://aimagin.com/blog. [Accessed on 9 June 2018].

[8] Wiwatwanichwong B, Suwanta P, Uttayotha W 2014 Automatic Gas Detection and Notification via GSM Network. *Senior Project*, Suranaree University of Technology Thailand.

[9] Jettarach J 2018 A Biogas Filler Prototype with an Unwanted - Gas Filter and Safety System. Master Thesis Kasetsart University Chalermphrakiat Sakon Nakhon Province Campus Thailand.

[10] Pramuanjaroenkij A, Phankhoksoong S, Tongkratoke A, Pathumwan K, Ponsukkhwa R, Thipruetri P 2018 The Behaviors of Three Different Transmission Systems between a Hybrid Engine and a Generator. Proceeding of the Fourth International Conference on Engineering and MIS, Istanbul, Turkey, 19-21 June 2018.