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Preliminary Study on Designing and Development of Biogas Analyser and Monitoring System using IoT

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ABSTRACT

Today, IoT enables traditionally dumb physical devices be control wirelessly from great distance. Other than that, local biogas related research and industry has grown into a new level which requires biogas analyser for measuring the gas content. The analyser currently is imported from other countries at a very high cost due to no local production. It is not easy to request for customisation of the analyser from its supplier. Therefore, this study aims to prove possibility on developing a portable biogas analyser with a monitoring system using internet of things (IoT) approach. The system uses Raspberry Pi microcomputer as core of the design. The analyser is capable of measuring methane (CH4) and carbon dioxide (CO2) which are main composition of biogas. The system includes a web server to allow monitoring from a distance via smartphones, tablets, and personal computers using any browser with Internet connectivity. An experiment was conducted to test both sensors used in the analyser. Based on the experiment, both sensors show a positive but unstable response towards respective gases. Thus, the sensors are suitable to be used for the analyser with some adjustment on its stability and accuracy. Furthermore, the web server proves to be stable throughout the experiment. In future development, more additional features will be added to the current web server along with analyser's case building and more experiments on the sensors. To summarize, this study shows it is possible to develop a biogas analyser with monitoring system using IoT approach locally which is still in progress. Moreover, with the success of this analyser in future, it will be a low-cost yet reliable alternative to the local researcher and industry.

Keywords:
Analyser, biogas, internet of things, monitoring system, Raspberry Pi

1. Introduction

Internet of things (IoT) enables a device to be controlled from great distance wirelessly. This feature has made the IoT, a trending technology currently being applied in our everyday life at an unprecedented rate [1]. Malaysia is leading in oil palm industry. Other than having an active agricultural activity, Malaysia also has abundant of biomass resources which have potential use in alternative energy or eco-products [2]. Biogas production from agricultural biomass [3] has great

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potential in local industry. With constant improvement of biogas production [4], local researchers and industry require biogas analyser for measuring biogas content ever than before. Currently, analyser is imported from oversea with a very high price; more than RM 20,000.00 per unit. This causes the local biomass industry to spend a high amount of money in such device with limited functionality. Other than that, it is not easy to request for customisation of the analyser from its supplier. Therefore, this study aims to prove possibility on developing a portable biogas analyser with a monitoring system using IoT approach with the following objectives; to study suitability and verify functionality of sensors to be used in the analyser, to design and develop a cost-effective portable biogas analyser with a web server, and to assess the system's performance. The system uses Raspberry Pi microcomputer as core of the design along with several other electronic components. The analyser is capable of measuring methane (CH_4) and carbon dioxide (CO_2) which are main composition of biogas. The system includes a web server to allow monitoring from a distance via smartphones, tablets, and personal computers using any browser with Internet connectivity. Since research on air quality monitoring system is the closest application related to this study that uses similar type of gas sensors, it was made as main reference of this study. Smartphone based design of air quality measurement system developed by Oletic and Bilas [5] and Hasenfratz *et al*., [6] has strength in portability and small size. However, the system is heavily dependent to the present of smartphone for usage and limited number of sensors can be installed into the system. Design using Arduino microcontroller as main processing unit such as air quality monitoring system developed by Ali *et al*., [7], wireless sensor network system for monitoring indoor air quality implemented by Abraham and Li [8], air quality measurement system for vehicles using Internet of Things (IoT) proposed by Rushikesh and Sivappagari [9], and microcontroller based temperature monitoring system implemented by Tayab and Yuen [10]. The common strength of their works is simplicity in design. However, limited capability of the Arduino in web server hosting makes it an unsuitable option. Reilly *et al*., [11] uses a Redboard microcontroller instead of Arduino in designing a wireless self-powered air quality measuring device which have rather the same features as the other Arduino based system. The design is unsuitable for this study's application due to the same reason as the Arduino based systems. System build using Raspberry Pi microcomputer such as smart gas detection system developed by Ilie and Vaccaro [12] shows advantage in supported features of the Raspberry Pi compared to Arduino and smartphone-based systems. Furthermore, environmental monitoring system developed by Deshmukh and Shinde [13] and Ibrahim *et al*., [14] illustrate possibility of combining several gas sensors into a single Raspberry Pi system for monitoring. Moreover, IoT based system that uses Raspberry Pi such as IoT based low cost air pollution monitoring system proposed by Parmar *et al*., [15], and the air quality monitoring system based on IoT using Raspberry Pi developed by Kumar and Jasuja [16], and smart environmental monitoring through IoT using Raspberry Pi 3 implemented by Sriyanka and Patil [17] show that Raspberry Pi is capable of supporting IoT based features. A study of pervasive monitoring of carbon monoxide (CO) and methane (CH_4) using air quality prediction by Karamchandani et al [18] is the closest reference of this study since it measures CH_4 gas as in this study. Based on past works, system design using Raspberry Pi as main processing unit is the best for this study's application. Wi-Fi is used in network layer of the IoT architecture for data transmission of the system as today high number users depend on Wi-Fi technology for Internet access [19]. With the completion of this analyser in the future, it can provide a cheaper alternative to the currently in market biogas analyser. This can save local industry for buying expensive imported gas analyser. Other than that, it will encourage locals to develop their own product for their own use rather than importing. Large scale production of the analyser locally will provide new jobs and boost the local economy.

2. Methodology

2.1 Internet of Things

Figure 1 shows the integration between gas analyser with monitoring system using Internet of Things (IoT) approach which extends capability of the original gas analyser to be a decentralise monitoring system. With this feature, the monitoring system can be access via any smartphones, tablets, or personal computers in great distance with Internet connectivity.

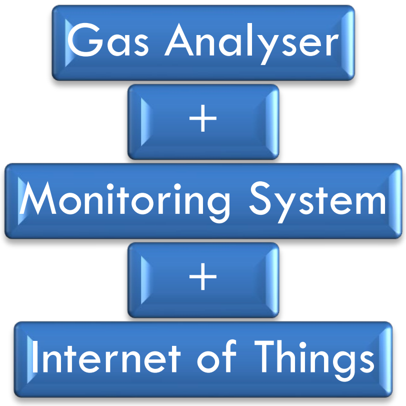

Fig. 1. Integration of the system

2.2 Hardware Design

In this study, a Raspberry Pi Model B microcomputer was chosen as core electronic component of the design as shown in Figure 2 (a). Data is processed, and web server is hosted from the Raspberry Pi. Readings retrieved from gas sensors is in parts-per-million (ppm) by default. The readings are then converted into percentage (%) value to suits its application as a gas analyser. A liquid-crystal display (LCD) screen is used to display the measured value on the analyser itself and a web server is used to display the measured value in a local network and on the Internet. The LCD screen is connected to the Raspberry Pi via its general-purpose input output (GPIO) port. To support its portability feature. A portable Wi-Fi modem is used to allow access to the system's web server locally and globally. The modem used supports virtual server for port forwarding to allow the web server accessible from the Internet. Other than that, the modem has a coverage of ten-foot radius of solid and consistent Wi-Fi signal. Moreover, the modem comes with a signal strength indicator for user's reference. The Raspberry Pi and modem communicate with each other via Wi-Fi. The modem also has an internal battery. However, the modem is connected via a universal serial bus (USB) port of the Raspberry Pi for charging to support long time usage. Another hardware required to support its portability feature is a portable power source. A 10 kmAh power bank is used to power up the system. The power bank supplies 5V voltage with 2.1A current. The power bank is connected to a 5V micro USB port of the Raspberry Pi. The power bank can hold the system on for up to five hours at full charged. Furthermore, the power bank also has a power level indicator. Since biogas only composes of two main gases, two sensors are used in the analyser. MQ-4 for measuring level of methane (CH_4) and MG811 for measuring level of Carbon Dioxide (CO_2). A logic level converter is required to lower output reading voltage of the sensors from 5V to a safe 3.3V before connecting it to the Raspberry Pi. An Analogue-to-digital converter (MCP3008) also is required to convert analogue output reading voltage from the sensors into digital which the Raspberry Pi supports. Detailed connection in form of a schematic diagram is shown in Figure 2 (b).

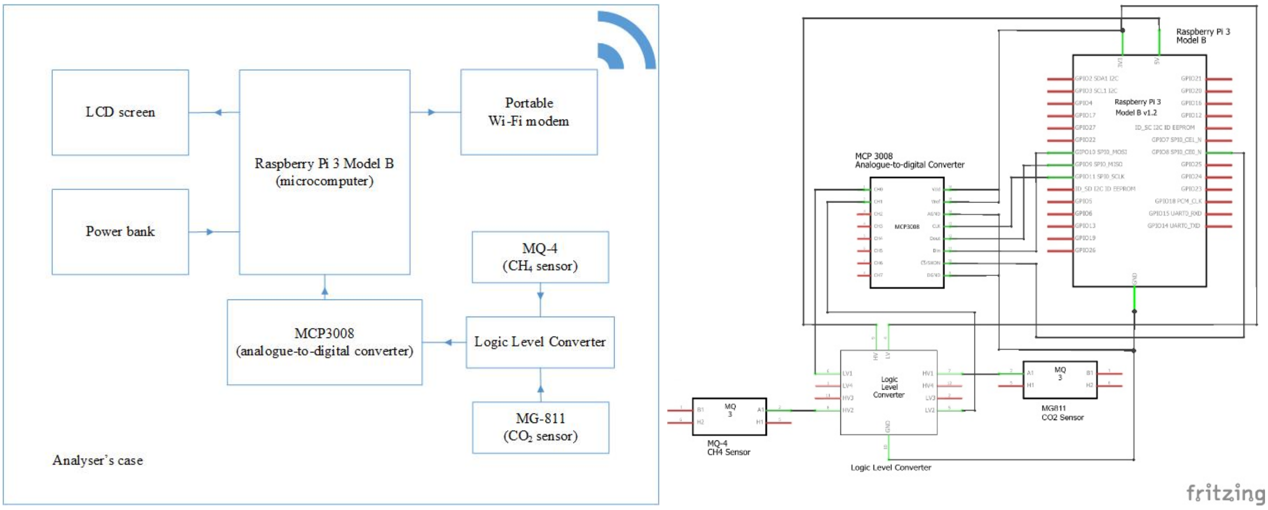

Fig. 2. Biogas analyser (a) Block diagram and (b) Schematic diagram

Proposed design for the analyser's case has three levels as shown in Figure 3. The upper level places the two sensors and where gas measurement takes place. A fluid pump was used to inhale gas from an inhale tube to flow through the sensors and out through an exhale tube. The LCD screen will be placed on this level for better view. Most electronic components will be placed in the middle level. Power bank and portable Wi-Fi modem will be placed at the lower level to ease replacement when necessary.

Fig. 3. Proposed case design

2.3 Software Design

Raspbian operating system is installed on the Raspberry Pi and several program scripts written in Python is made to run the system. Figure 4 shows the flow chart of the program scripts in overall. As the analyser is turned on, it starts measuring concentration level of CO_2 and CH_4 gas in parts-per-million (ppm) value. The ppm value is then converted into percentage (%) value and displayed on the LCD screen and the web server. The program is looped, and the readings is updated on average of every five seconds. The web server is made in python and hosted from the Raspberry Pi. The web pages were made in hypertext markup language (HTML) and cascading style sheets (CSS). The web server was made to ease user monitoring on any browser from great distance using Internet connectivity via smartphones, tablets, and personal computers.

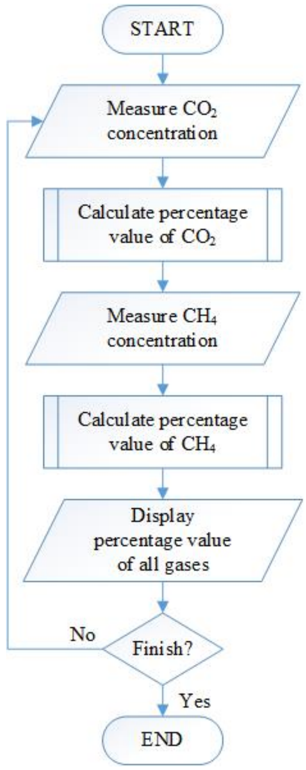

Fig. 4. Flowchart of the program scripts

Accessibility is among main feature of the system. This feature directly relates with the web server which is accessible locally via the system's Wi-Fi (BAMS) and globally via the Internet. A local telco's data (Internet) subscription is only necessary for global connection. Locally, the system can be accessed by connecting to the system's Wi-Fi and using its local internet protocol (IP) address as uniform resource locator (URL); http://192.168.1.203:8080 at a browser. While globally, the system can be accessed via a browser with the following URL; http://bams.duckdns.org:8080. For both situations, the analyser must be turned on first before it can be accessed. Other than that, the system includes basic security measures such as Wi-Fi login popup to prevent unauthorised access and Internet connection login popup to avoid unintended connectivity to the Internet. BAMS stands for biogas analyser and monitoring system.

2.4 Experiments on the Sensors

The experiment was carried out in a laboratory to verify the two sensors which can measure CH_4 and CO_2 gas, respectively. The gas with composition of 54 % CH_4 and 35% CO_2 was obtained from biogas plant at Cenergi Sdn Bhd and it used in the experiment. The experimental setup is as shown in Figure 5. The sensors are calibrated before the experiment. By default, reading value from the sensors is in parts-per-million (ppm). The reading is then converted into percentage (%) value using Eq. 1 by the Raspberry Pi. To verify the sensors as working, there should be an increase in reading when the gas is released into the sensor's container.

$$Gas\ concentration\ (\%) = \frac{Gas\ concentration\ (ppm)}{10,000} \quad (1)$$

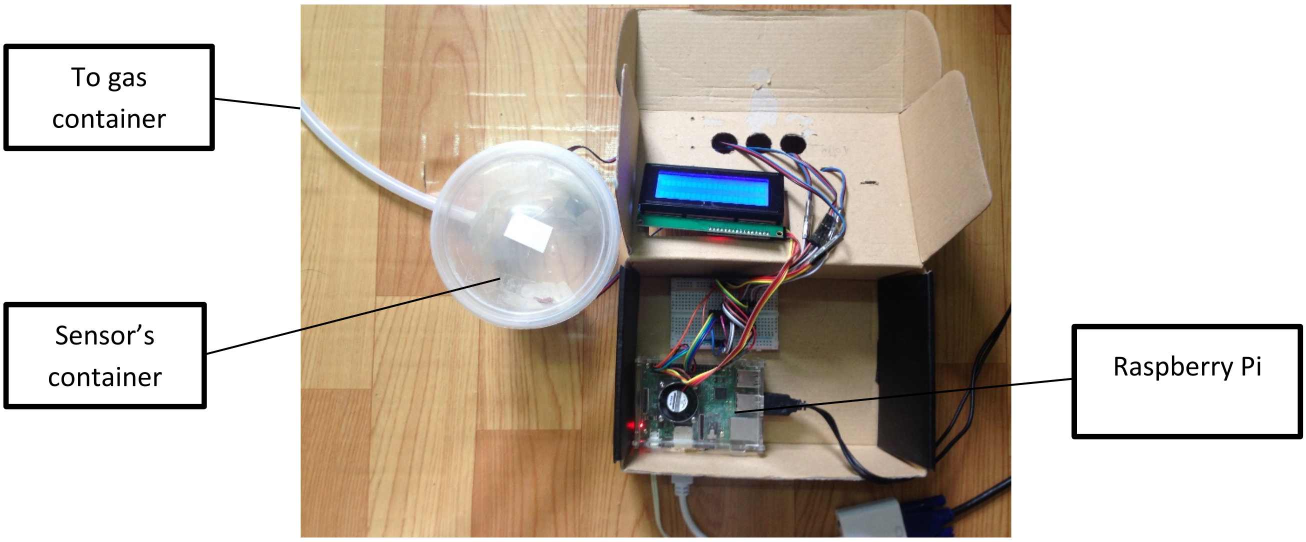

Fig. 5. The experimental setup

3. Results

The electronic components had been assembled successfully inside a box as its temporary case. Currently in development stage, direct power supply (plugged) is used to ease work without having power shortage issue. Other that that, a monitor, keyboard, and mouse is used for controlling the system for this stage. The system runs smoothly without any problem until it is turned off as designed. Figure 6 shows the web pages from the web server displaying gas reading in percentage and ppm which is viewed from a personal computer in a local network using the system's Wi-Fi. Thus, the monitoring system is working as expected without any issue.

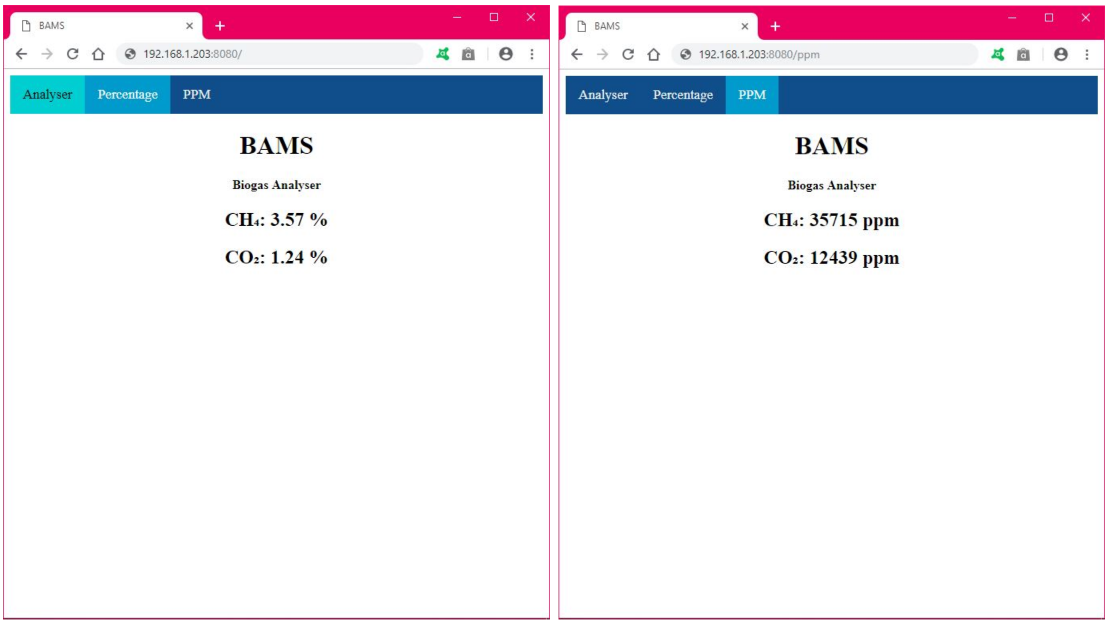

Fig. 6. Measurement page in (a) percentage and (b) ppm

To verify the sensors, both sensors were expected to detect present of respective gas with reading near to the gas composition. Based on result shown in Figure 7, both sensors' reading fluctuated. However, lower point of the fluctuated reading of MQ-4 sensor and upper point of the fluctuated reading of MG811 sensor seems to be close to the respective gas composition value.

Both sensors show consistency in reading but unstable due to factors yet to be known. However, the sensors are verified as usable with the consistency and closeness of its reading to the gas composition. The unstable reading can be resolve in future work by adjustment to its calibration and measurement mechanism. Thus, both sensors are suitable to be used in the analyser. In overall, the system is working well as designed and shows a positive feedback encouraging for future development of the system.

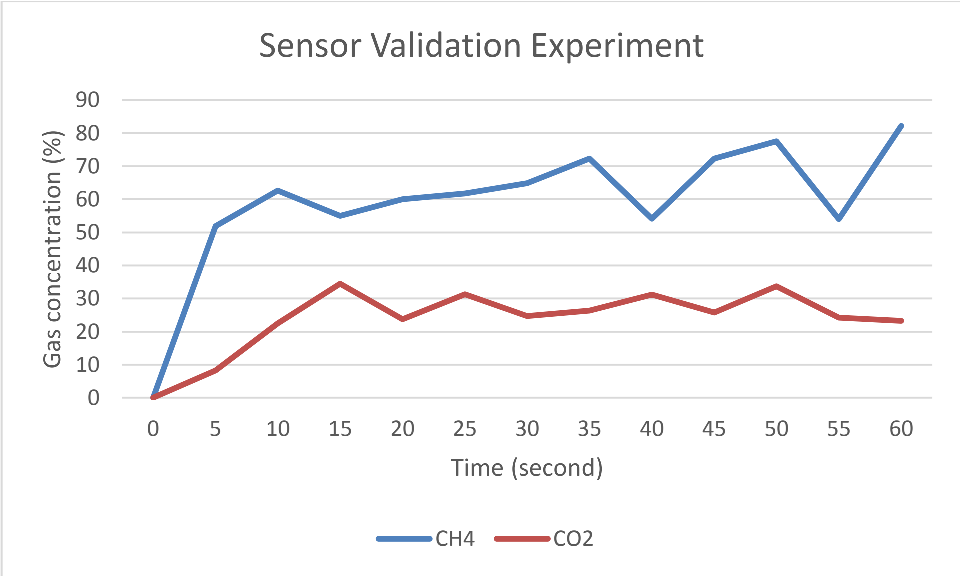

Fig. 7. Results of sensor validation experiment

4. Conclusions

Hardware part of the analyser was partially done with only case for analyser yet to be designed and made. Meanwhile, software part of the analyser proved to be reliable without having a crush during the experiment. Other than that, a global web server was hosted successfully for displaying readings from the system. Both sensors selected was verified its functionality in the experiment and suitable to be used in the analyser's design. The sensors were verified in the test. This shows that both sensors are suitable to be used in the analyser's system. This study proves the possibility to produce such a system. This study will be proceeded with designing and making a case suitable for portable usage of the analyser, optimising the current system in term of accuracy and reliability, and run a full-scale test on the entire system.

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