Design and Implementation of a Real-Time Monitoring System Based on Internet of Things in a 10-kW Downdraft Gasifier

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https://doi.org/10.5109/4774230

出版情報：Evergreen. 9 (1), pp.145-149, 2022-03. Transdisciplinary Research and Education Center for Green Technologies, Kyushu University
バージョン：

Design and Implementation of a Real-Time Monitoring System Based on Internet of Things in a 10-kW Downdraft Gasifier

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(Received February 11, 2022; Revised March 22, 2022; accepted March 22, 2022).

Abstract: A gasifier produces synthetic gas from the gasification of biomass wastes, such as rice husks. Synthetic gas produced through the gasification process can be an alternative fuel for gas engine generators or gas burners. The biomass gasification system in Indonesia has a huge potential for implementation because of the high electricity demand and imbalanced distribution of power plants. The gasification process is quite complicated. Hence, it is imperative that during the operation, real-time data are sent to operators for monitoring. In this study, we design an Internet of Things (IoT)-based system for transmitting data of frequencies from motors and temperatures from a reactor to an Android application. Then, the obtained data from a panel, graphical user interface (GUI), and IoT are analyzed for their delay and accuracy. As a result, the mean values of delay are 0.43 and 3.67 s for GUI and IoT, respectively. In addition, the accuracy is assessed using the mean absolute error with values of 0.15, 0.1, 0.09, and 0.12 for motors at a screw feeder, vibrating grate, primary blower, and exhaust blower, respectively.

Keywords: Gasification; IoT; Android

1. Introduction

Energy is crucial to people's lives because almost all human activities require energy. However, yearly, the use of energy continues to increase; in 2019, the total global fossil fuel consumption was 136.761 TWh, whereas the total renewable energy consumption was only 18.138 TWh[1,2]. Moreover, biomass has a huge potential as a source of renewable energy. Biomass wastes can be used by converting them into synthetic gas via a gasification process[3-5].

Our research group in Universitas Indonesia devised a prototype biomass gasifier[6]. The prototype has a downdraft design and a 10-kW capacity. In the near future, the prototype will be installed in remote places with an imbalanced distribution of power plants, although the gasification process is quite complicated[7]. Therefore, it is imperative that when operating a gasifier, data are transmitted in real time to operators stationed in a different location to monitor the operation. In this study, we designed and implemented an Internet of Things (IoT)-based monitoring system for a 10-kW-capacity gasifier[8,9]. After implementing the IoT-based system to the gasifier, the system performance is evaluated. The evaluation was performed by calculating the delay and accuracy of transmitted data. The delay was calculated by measuring data transmission time, whereas the accuracy was calculated using the mean absolute error (MAE).

2. Materials and methods

2.1 Biomass gasifier

A downdraft fixed-bed gasifier, which incorporated improvements from the previous prototype, was the main focus of this study[6]. Figure 1 depicts the prototype, and Figure 2 shows the piping and instrumentation diagram. The gasifier used risk husk as the feedstock and had an overall installed capacity of 10 kW with alternating current motors installed at various positions, serving as actuators[10]. The actuators maintained the temperature of the reactor in its gasification range. Table 1 shows the gasification temperature range in the reactor.

Fig. 1: Prototype gasifier

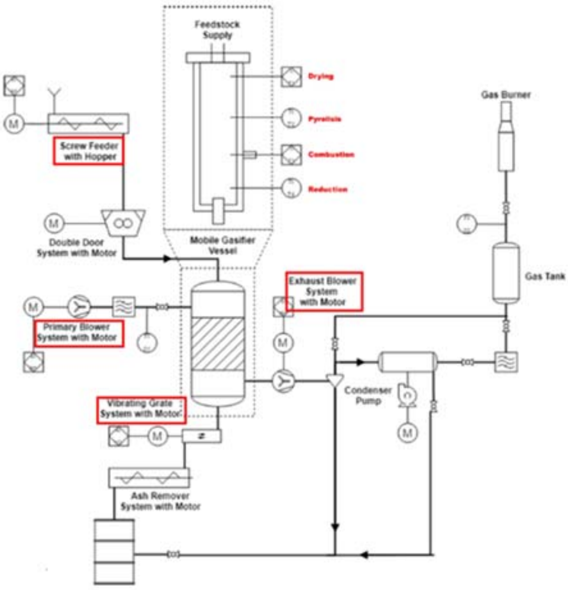

Fig. 2: Piping and instrumentation diagram of a 10-kW downdraft gasifier system used in the experiment

Table 1. Temperature range of each zone in the gasifier reactor

Reactor Zone	Temperature (°C)
Drying zone	100–200
Pyrolysis zone	200–700
Combustion zone	700–1,000
Reduction zone	500–600

2.2 IoT-Based System

The IoT-based system provides data, such as the operational parameters of the gasifier, for users. Figure 2 (a) shows the workflow of the IoT-based system. The underlying parameters are temperatures at a reactor and frequencies of motors. Data are transferred to a Raspberry Pi through Modbus and universal serial bus communications. From the workflow of the IoT-based system, part of the system is an electronic circuit system (Figure 2 (b))[11]. Analog signals in the form of frequencies from motors were converted to digital signals by Arduino and transmitted to a Raspberry Pi through serial communication[12,13]. Modbus communication from temperature-modulated heteroduplex analysis or temperature control will be transferred to a Raspberry Pi through Modbus485 communication and supported by Modbus Python. The Raspberry Pi power was connected to an adapter that converts voltage from 220 VAC to 5 VDC. The data on the Raspberry Pi were processed into a graphical user interface (GUI), which were stored in the form of comma-separated value (CSV) files, and sent to Google Firebase with an internet connection. Raspberry Pi 4 was employed in the proposed system, and the software was written in Python[14-16]. The Android system performed a synchronization with Google Firebase so that the data displayed on the Android application are real[17,18]. After the electronic circuit was arranged and effective software functioning was ensured, the IoT-based system was placed in a three-dimensional (3D)-printed protective box. The 3D-printed protective box is shown in Figure 2 (c). The protective box protects the electronic system from dust and vibration.

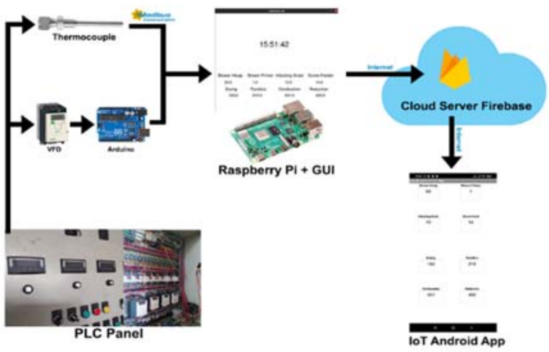

Fig. 3: IoT-based system workflow

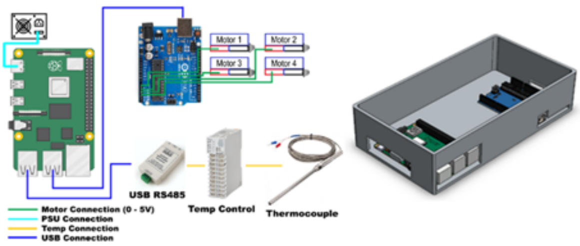

Fig. 4: Electronics circuit system and 3D- printed protective box

The actual results of the IoT-based system are shown in Figure 3 (a). The system was placed on a programmable logic controller (PLC) panel so that cabling could be close to the main system. By combining the hardware and software, the IoT-based system could operate properly according to the objectives[19]. The IoT software featured a GUI, which displays eight parameters: frequencies from four motors and temperatures from four zones in the reactor. Subsequently, the parameters from the GUI were sent to the Android application for data logging and saved as CSV files. Thus, the data are prepared for further study of delay and accuracy. In addition, the IoT software had a GUI and Android application for ease in operation. Figure 3 (b) shows the GUI on a Raspberry Pi written in Python, and the Android application shown in Figure 3 (c) was written using the MIT App Inventor[15,20].

Fig. 5: IoT-based system hardware and Software

2.3 Delay and Accuracy Tests

Delay and accuracy tests were performed three times. Every test was completed by changing the motor frequency variable by adjusting each potentiometer on the PLC panel from zero to twenty. The value adjustment was performed every 10 s for each increment from 1 to 20 Hz. Then, the values displayed on the PLC panel, GUI, and Android application were recorded accordingly.

3. Results and discussions

From the results of the delay and accuracy tests, the data from the first experiment were processed into a graph (Figure 4). The presented data are frequencies of the motors at the primary blower, exhaust blower, vibrating grate, and screw feeder, corresponding to Figure 1 (b). All experimental data from the first to the third test were then reprocessed with the mean and MAE (Figure 5).

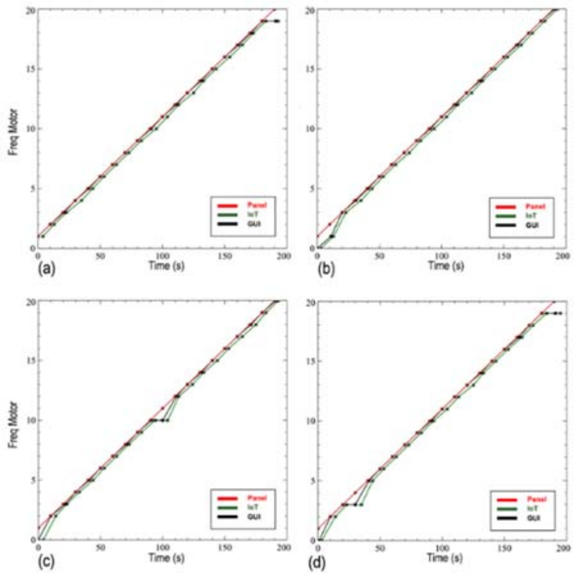

Fig. 6: Data of frequencies of motors at a) primary blower, b) exhaust blower, c) vibrating grate, and d) screw feeder

Figure 5 (a) shows the graph of the mean delay values recorded in the GUI and Android application, labeled IoT. The connection from the PLC panel to GUI was direct with a cable, so the delay was short, with a mean value of 0.43 s . Meanwhile, data transmission from the PLC panel to IoT, encompassing a cloud server as an intermediary, had a relatively large delay value with a mean of 3.67 s. Nevertheless, with the mean waiting time generated by IoT, the IoT-based system is feasible to implement in the gasifier prototype because changes in the motor frequency values were performed every 3–5 min; hence, a mean delay of 3.75 s did not have a significant effect. In addition, compared with a recent study on IoT delay performance[21], the network protocol, Google Firebase, had a threefold higher delay time than other network protocols, such as Message Queuing Telemetry Transport (MQTT) and Extensible Messaging and Presence Protocol (XMPP)[22,23]. The advantage of using Google Firebase as a network protocol is that the IoT device is easily build.

Figure 5 (b) shows the graph of the MAE for each motor's connection line. The MAE value is generally due to noise, which causes data provided by the potentiometer by Arduino to have a relatively high level of oscillation of up to 0.15 in the MAE. The difference in the motors did not yield a significant difference in MAE because each motor did not vary enormously, namely, 0.15, 0.1, 0.09, and 0.12 were channeled to IoT without any difference[24]. In addition, compared with a recent study on IoT accuracy performance[25], we obtained a better MAE value because the designed IoT-based system did not use algorithms to improve accuracy. The recent research can be improved using the Kalman filter algorithm to reduce MAE.

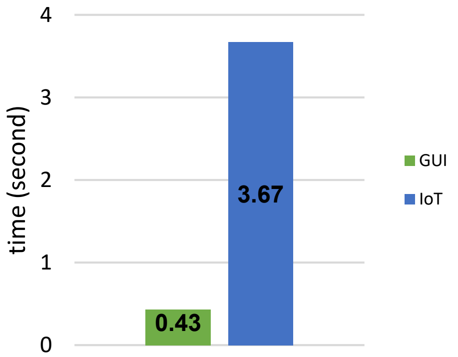

Fig. 7: Delay average

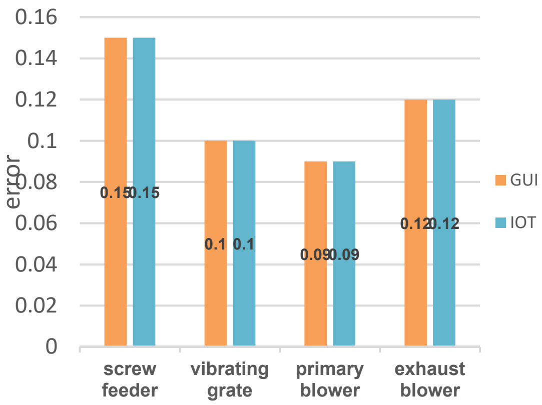

Fig. 8: Mean absolute error

4. Conclusion

In this study, an IoT-based system was designed in a 10-kW-capacity gasifier. The accuracy was calculated using the MAE, yielding the same value for each connection, i.e., 0.15, 0.1, 0.09, and 0.12 for screw feeder, vibrating grate, primary blower, and exhaust blower, respectively. The IoT-based system delay produces mean values of 0.43 and 3.67 on a GUI and IoT, respectively. Although the delay in IoT was more profound than in GUI, the level of delay had no significant influence on IoT performance because the motor values usually renewed every 3–5 min. The future design of IoT-based systems will improve the delay and accuracy and be tested in a natural environment in a rural setting.

References

1) B. Dudley, "BP statistical review of world energy," BP Statistical Review, London, UK, Accessed Aug, 6 (2018) 00116 (2018).
2) Y. Furutani, K. Norinaga, S. Kudo, J. Hayashi, and T. Watanabe, "Current situation and future scope of biomass gasification in japan," Evergreen, 4 (4) 24–29 (2017). doi:10.5109/1929681.
3) P. Basu, "Biomass gasification and pyrolysis: practical design and theory," Academic press, 2010.
4) K. Ibadurrohman, I. Gusniani, M.D. Hartono, and N. Suwartha, "The potential analysis of food waste management using bioconversion of the organic waste by the black soldier fly (hermetia illucens) larvae in the cafeteria of the faculty of engineering, universitas indonesia," Evergreen, 7 (1) 61–66 (2020). doi:10.5109/2740946.
5) Nining Betawati Prihantini, N. Rakhmayanti, S. Handayani, W. Sjamsuridzal, W. Wardhana, and Nasruddin, "Biomass production of indonesian indigenous leptolyngbya strain on npk fertilizer medium and its potential as a source of biofuel," Evergreen, 7 (4) 593–601 (2020). doi:10.5109/4150512.
6) L. Andromeda, A. Surjosatyo, H. Dafiqurrohman, and M.H. Amirullah, "Analysis of fix bed downdraft biomass gasification reactors continues operating characteristics towards synthetic gas quality," in: AIP Conference Proceedings, AIP Publishing LLC, 2020: p. 030050.
7) Y. Furutani, K. Norinaga, S. Kudo, J. Hayashi, and T. Watanabe, "Current situation and future scope of biomass gasification in japan," (2017).
8) R. Imansyah, "Impact of internet penetration for the economic growth of indonesia," Evergreen, 5 (2) 36–43 (2018). doi:10.5109/1936215.
9) A. Mankotia, and A.K. Shukla, "IOT based manhole detection and monitoring system using arduino," Materials Today: Proceedings, (2021). doi:10.1016/j.matpr.2021.12.264.
10) Hidayat Furqon Hanif, Dhelika Radon, Setiawan Rahman, Dafiqurrohman Hafif, and Surjosatyo Adi, "Investigation of relative influence of process variables in a 10 kw downdraft," (2020).
11) K.C. Meje, L. Bokopane, K. Kusakana, and M. Siti, "Real-time power dispatch in a standalone hybrid multisource distributed energy system using an arduino board," Energy Reports, 7 479–486 (2021). doi:10.1016/j.egyr.2021.08.016.
12) M. Bansal, A. Agarwal, M. Pant, and H. Kumar, "Challenges and opportunities in energy transformation during covid-19," Evergreen, 8 (2) 255–261 (2021). doi:10.5109/4480701.
13) R. Irwansyah, F. Juana, Y. Whulanza, and J. Charmet, "Heating characterization of low energy consumption lab-on-a-chip," Evergreen, 8 (4) 872–878 (2021). doi:10.5109/4742135.
14) R. Karunamoorthi, M. Tiwari, T. Tiwari, R. Kuruva, A.K. Sharma, M. Jemimah Carmichael, and T.C. Manjunath, "Design and development of iot based home computerization using raspberry pi," Materials Today: Proceedings, (2020). doi:10.1016/j.matpr.2020.10.673.
15) A.E. Amoran, A.S. Oluwole, E.O. Fagorola, and R.S. Diarah, "Home automated system using bluetooth and an android application," Scientific African, 11 e00711 (2021). doi:10.1016/j.sciaf.2021.e00711.
16) Hoedi Prasetyo, "On-grid photovoltaic system power

monitoring based on open source and low-cost internet of things platform," Evergreen, 8 (1) 98–106 (2021). doi:10.5109/4372265.
17) W.-J. Li, C. Yen, Y.-S. Lin, S.-C. Tung, and S. Huang, "JustIoT Internet of Things based on the Firebase real-time database," in: 2018 IEEE International Conference on Smart Manufacturing, Industrial & Logistics Engineering (SMILE), IEEE, 2018: pp. 43–47.
18) A.E. Amoran, A.S. Oluwole, E.O. Fagorola, and R.S. Diarah, "Home automated system using bluetooth and an android application," Scientific African, 11 e00711 (2021).
19) S. Choudhary, A. Sharma, K. Srivastava, H. Purohit, and M. Vats, "Read range optimization of low frequency rfid system in hostile environmental conditions by using rsm approach," Evergreen, 7 (3) 396–403 (2020). doi:10.5109/4068619.
20) K. Chadha, and F. Turbak, "Improving app inventor usability via conversion between blocks and text," Journal of Visual Languages & Computing, 25 (6) 1042–1043 (2014). doi:10.1016/j.jvlc.2014.10.005.
21) A. Kondoro, I. ben Dhaou, H. Tenhunen, and N. Mvungi, "Real time performance analysis of secure iot protocols for microgrid communication," Future Generation Computer Systems, 116 1–12 (2021).
22) V. Seoane, C. Garcia-Rubio, F. Almenares, and C. Campo, "Performance evaluation of coap and mqtt with security support for iot environments," Computer Networks, 197 108338 (2021). doi:10.1016/j.comnet.2021.108338.
23) P. Arivubrakan, and K. Prema, "The routing based protocol technique for enhancing the performance metrics using mqtt in the internet of things," Materials Today: Proceedings, (2020). doi:10.1016/j.matpr.2020.11.070.
24) T. Chai, and R.R. Draxler, "Root mean square error (rmse) or mean absolute error (mae)?–arguments against avoiding rmse in the literature," Geoscientific Model Development, 7 (3) 1247–1250 (2014).
25) X. Lai, T. Yang, Z. Wang, and P. Chen, "IoT implementation of kalman filter to improve accuracy of air quality monitoring and prediction," Applied Sciences, 9 (9) 1831 (2019).