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Telemonitoring Temperature and Humidity at Bio-energy Process using Smart Phones

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Abstract

Bio-energy from biogas can be produced through anaerobic digestion of either organic solid waste or wastewater. Energy production process in the digester is however sometimes hard to be monitored due to manual measurement, otherwise it needs a high technology requiring a high cost budget. This paper presents a low cost technology to monitor the process by using Android based smart phones which can easily be integrated in human daily activity. A program was built by using Eclipse in order to give send/receive command to/from the hardware and display the measurement data on the registered smart phones. The measurement controller was put at the anaerobic digester to record temperature and Relative Humidity (RH) data to memory card and to transmit the data to smart phones. In the experiment with 20 data samples, mean errors were repectively -0.317 ^{o}C, 0.932 ^{o}C, and 1,378 % for temperature sensor LM35, and temperature and RH sensor using SHT11. Mean squared error for LM35 was 0.373 ^{o}C and for SHT11 was 1.117 ^{o}C and 2.629 % for temperature and RH respectively. The system has been also implemented in the real anaerobic digester. Electrical energy consumption was 0.623 Wh with 30 minutes cycle time and one minute sampling time.

Keywords: *Renewable energy, Telemetry, Android, Automation, Anaerobic digestion*

1. Introduction

Biogas is one of the renewable energy sources which is currently receiving increased attention mainly due to its high electrical efficiency and low environmental impact [1] as well as to substitute or at least to reduce the use of conventional fossil fuels. Biogas mainly consists of Methane produced from anaerobic decomposition of organic waste in a controlled landfill representing as a digester. Methane potentially composes bio-energy which can be used to generate electricity and heat, or even transformed into other kind of energy. Temperature and relative humidity (RH) have an important role in biogas fermentation [2]. The potency analysis example of a biogas production with a case study in landfill Pontianak Indonesia can be seen in [3]. Data of temperature and RH are necessary to analyze the bio-energy system regarding its application for biogas energy systems [4]. Along with the rapid development of technology and the increasing human mobility, supervision and data acquisition of a process is very important to be done. Telemetry system as remote measurement system can be applied for these purposes. This system can improve the efficiency and ease supervision and data acquisition the energy production process in anaerobic digester anywhere and anytime.

However, the use of current sophisticated technology has raised the problem for the implementation of supervision and data acquisiton in terms of telemonitoring bio-energy process in anaerobic systems operated in developing countries. High capital budget and lack of technical capabilities on using the technology are the most common reasons. Building a new communication infrasturucture is also another problem to be solved, since many locations in developing countries lacking of communication infrastructure. Therefore, a low cost technology for telemonitoring the process will economically be acceptable to be used in developing countries. The technology has to consider the common infrastructure available at the location where the system will be implemented.

A solution proposed in this paper is to use Android-based smart phone as a reader of the telemetric temperature and RH at anaerobic system. Smart phone based on Android operating system (OS) used in this research since it is one of the popular OS which controls

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about 80% of global smartphone market for the last several years even reach 84.7% in the 3rd quarter of 2015 [5]. This kind of smart phone has been used dominantly in developing countries due to the simplicity to get the application installers which are mostly free of charge. Android is an open source programming that can be modified to add unavailable features. Since it is open to be developed, the application extension is restricted by human programing capability. Telemetry systems using Android is still not commonly used. By considering its advantages, mobile telemetry systems using Android is potentially to be developed in order to solve the problem of the conventional technology. In fact, measurement of temperature and RH at the anaerobic digester is generally still done manually especially in developing countries, such as landfill in Indonesia and also in previous research [6, 7]. The mobile monitoring system will improve efficiency and capability of the analysis.

There has been several telemetry systems non-Android based developed on different applications through various technologies. An example of application of telemonitoring using web-SCADA (Supervisory Control and Data Acquisition) to monitor wind-photo voltaic power system can be seen in [8]. SCADA is one of the sophisticated technology, some problems mentioned ealier may raise for the implementation in developing countries. A telemetry system based on Web interafece is proposed to measure the temperature can be seen in [9] on the hot steam diverter pipe via Radio-Frequency Identification (RFID) with short measurement range and in [10] on the high-voltage equipment. Similar to the web-SCADA, these systems also need server to support the Web. Furthermore, telemetry system based on Java ME (Micro Edition) has been proposed in [11]. Although Java ME is open source, but the hardware specifications based on Java ME phones lower than on phones with Android operating system, and also less popular than Android phones, especially in developing countries.

In many studies of telemetry systems that have been presented, telemetry systems using Android based phone as the interface is still not commonly found. Each of researchers used various in delivery of measurement data, and the difference form of hardware and software as well as the parameters measured. A telemetry system with Android using efficient transmission techniques has been designed in [12] through Tmote Sky and using wireless local area network (WLAN) as a communication device to Android, it had drawbacks on distance limitations of WLAN coverage and power consumption large electric WLAN devices. Bluetooth was used in [13] as the communication to the Android device, together with WLAN, Bluetooth has a range shorter transmission range of about 10 meters, although the electric power used more sparingly. One of the communications media that has a broad reach and away is the internet, such as presented in [14]. Yet it needed a WEB server and the cost of hosting a WEB Server which is not cheap [15]. SMS Gateway has been used in [15] as the link to the Android device microcontroller. SMS has an extensive network and does not require WEB Server as SMS already has its own service center provided by the provider. Moreover, its interface to the microcontroller is easier to be done. In the current researches about the study of telemetry systems using Android-based phone, the interface on Android application was designed to have a simple shape such as in [12-15]. Those papers however describe the measurement of data without the time display of measurement and not in the form of tables or graphs, while in [14], it did not show what kind of interface which was created. Another example of application of Android for online monitoring in Agriculture and Biomedical Engineering can be seen in [16-21].

In the mentioned application, it can be seen that there is rare application of Android based smartphones measurement systems in anaerobic digester to monitor the biogas energy production process. This paper will present an autonomous monitoring system related to this application. To facilitate retrieval of data measurement, a telemetry system would be very helpful. In the presented paper, the developed telemetry system could record data through the application to be available for acquisition on Android smartphones and was also being equipped with a data storage media such as Secure Digital (SD) Card on the hardware part. Later on, the interpretation of the data can be used for supervision to the system conditioning.

2. Research Method

Figure 1 shows a schematic diagram of the developed telemetric measurement system for temperature and RH. There are two parts based on the location which are access module and measurement module. Access module is purposed to receive the measurement data which later on will be processed and display on Android based smart phones or tablets. Measurement module has main functions to get the data through sensor circuits, to process the data through microcontroller, to display the data using liquid crystal display (LCD) and to transmit the data to smart phone(s) with the mobile number that has been set in the microcontroller. The system design was divided into two parts: hardware and software.

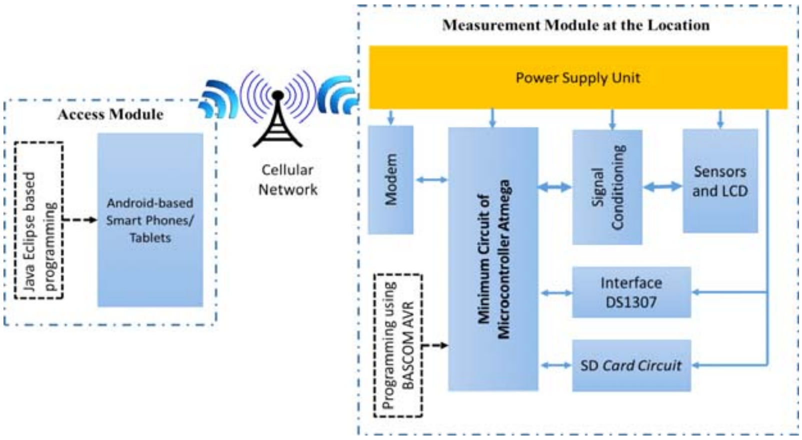

Figure 1. Autonomous telemetric measurement system

2.1. Hardware Design

The hardware consists of control system components (i.e. controller, sensor and display) and communication. Some components are explicitly displayed in Figure 1. The controller was designed by using AVR microcontroller ATMega1284P with basic programming language using Bascom AVR Software. A minimum circuit microcontroller bases on the calculation of power supply using Ohm law and required clock. A Wheatstone bridge circuit has also been used for voltage regulation. The analog to digital converter (ADC) was applied to make the measurement signal can be computed in the microcontroller.

There are three parameters measured, i.e. temperature outside and inside the biogas digester, as well as the RH around the digester. Communication between the microcontroller and Android used Wavecom M1306B GSM modem via Short Message Service (SMS) Gateway. Telemetry interface on Android application is made by software that has been integrated with Java Eclipse Android Development Tools (ADT) Plug-in, and use the Java programming language and XML. LM35 sensor is wrapped with stainless steel probe as a temperature sensor inside the digester, and SHT11 as temperature and RH sensor outside the digester. For data storage media used Secure Digital Memory Card (SD Card) that is compatible with Multi Media Card (MMC). The SD card was to accommodate the data before it was sent to be used as the backup data that can be retrieved at any time and make it easier for long-distance data transmission in the form of data packets. The maximum capacity of SD Card used measuring 8 GB. Applications built implemented for the Android smart phone devices equal or above version 2.1 (Eclair) and does not address the cost of sending an SMS.

The main power supply uses a battery 12 V placed at the location of measurement. Microcontroller, RTC DS1307, SHT11 sensors, and sensor DS18B20 had a working voltage of 5 V, while the SD card requires a voltage of 3.3 V. Therefore, the SD Card needed a voltage regulator IC Low Dropout Regulator (LDO) with type L7850 to 5 V and AIC1722A-33P to a voltage of 3.3 volts. The microcontroller has a logic voltage of 5 volts on condition HIGH. While the SD card 2.8 volts to 3.6 volts to satisfy the conditions HIGH. Consequently, to avoid potency of damaging the SD card, a voltage divider was implemented.

In order to save the date and time when the system is running but power supply is turned off, a Lithium Cell 3 V battery was used. Communication with a convenient SD Card used a Serial Peripheral Interface (SPI).

Modem used was one type of modem Fastrack M1306B Wavecom. It supports AT-Command communication with RS232 serial output. There are different levels of communications using this modem, therefore IC MAX232 used as an interface in order to be able to communicate properly. The IC has pins TX and RX RS232 for transmitting and receiving data respectively. They are then connected to the pin TX and RX modem GSM null-modem or TX and RX crossed each other as if the communication is done by two the same equipment without any control signal. To set the communication at the same speed (i.e. 9600 bps), the modem and the microcontroller must then be set the same communication speed. Default baud rate modem M1306B is 115200 bps, but with 8 MHz crystal used in microcontroller communication speed, it is not possible. Therefore the speed of the modem must be set back. Rearrangement of speed baud rate was done using AT-Command AT + CIFR = 9600. The order is temporary speed configuration means that do not already stored in the EEPROM memory modem, and if the power supply is turned off, the configuration will return to 115200 bps. Storage speed settings in EEPROM uses AT-Command AT & W. Relations between the modem and the microcontroller was performed only using pin TX and RX without involving pin wiring configuration control so both must use a null-modem configuration, wherein this configuration crossing the cables between TX and RX. Moreover, type of communication Dallas-Maxim DS1307 (Interface to the microcontroller) Real Time Clock (RTC) is I2C. ATmega1284P has hardware I2C on its port. RTC DS1307 requires two pieces of pull-up resistors. XTAL (Crystal) with value 32.768 kHz was used.

LM35 temperature sensor has an analog output signal so that ADC is required. ATmega1284P microcontroller has an internal 10-bit ADC port. In this research, the sensor was connected that port. The sensor was then wrapped using a probe made of stainless steel to be water proof. RH is a ratio describing a percentage of the actual water vapor pressure to the saturated vapor pressure at a certain temperature [22]. Meanwhile, according to Damian, et al. [23], RH is the percentage of saturated vapor pressure which describes the actual vapor pressure, in other words the ratio of air humidity in the atmosphere at the moment with a maximum humidity that can be accommodated by the atmosphere. RH percentage is calculated as follows,

$$RH = \frac{p(H_2O)}{p^*(H_2O)}\ x\ 100\% \qquad (1)$$

where

p(H2O) : partial pressure of water vapor in the mixture
p*(H2O) : saturated vapor pressure of water in the mixture

Furthermore, to connect the sensor and microcontroller ATmega1284P to temperature and RH sensor namely SHT11, two-wire Serial interface communication was used. This communication requires two pins from one microcontroller port. Pull-up and pull-down resistors were used to create a logic state on the path HIGH DATA fixed on the conditions when there is no signal from the microcontroller. The converse pull-down resistor to make logic state on line CLK (clock) becomes low when no signal from the microcontroller. Sensor SHT11 used a module named artificial Innovative Electronics DT-Sense SHT11. This module already has a pull-up and pull-down resistors.

2.2. Software Design

There are two main parts in software design, which are microcontroller and android-based smartphone programming. In general, the working configuration of the telemetric measurement system can be set offline and online. Offline setting typically use computers contain readers and writers program for the EEPROM microcontroller since the parameters are commonly stored in it. In the research presented in this paper, the offline setting was not carried out using a computer but through file in the SD card containing a few lines of code. The file would always be read by the microcontroller in the beginning and then the parameters were stored in the EEPROM. A *config.ini* file embedded in the SD Card used as a control of the autonomous telemetric measurement system. For instance, the first line in coding in this file was the sampling time of recording data to the SD Card in minute, while the second line was the recipient of a number of Android phones.

At the beginning microcontroller turned on, it will check and read the existence of this file. Reading was then performed sequentially line by line and the information was stored in each variable to be used in the next algorithm. The software in the microcontroller consisted of several main function such as acquiring the necessary data, storing data and sending it. The coding was built by using BASCOM AVR programming language. The coding consisted of two algorithm, namely main and interruption algorithm (SMS configuration and commands in Android application). On startup process, microcontroller did configuration which is mainly for external equipment such as GSM modem, internal temperature sensors and devices used to detect incoming SMS interruptions. As long as there is no interruption of the microcontroller performing routine activities of reading time and date, temperature and RH data from the sensors.

There was also interrupt routine program. This program was meant to change some system configurations via remotely using SMS containing specific text. Interrupt vector RS232 was turned on since the microcontroller started up. It was used to detect the reception of characters from the modem. If there are characters sent by modem to a microcontroller, then the interrupt vector would carry out routine checks to know the contents. Character AT-Command indicating the incoming SMS is "AT + CNMI". If it is correct, then it is followed with reading SMS (AT + CMGR). Once the mobile number is matching, the content of SMS is compared with an SMS code stored in the EEPROM to determine which command to be run. The command codes are listed in Table 1.

Table 1. Command list for Interruption routine

No	Text command	Command
1	#RST	Reset microcontroller
2	#10 minutes	Send measured data in the last 10 minutes
3	#30 minutes	Send measured data in the last 30 minutes
4	#n	Change sampling time (n), $1 \le n \le 59$

There are three things to do in the interrupt routine algorithm. Firstly, reset the microcontroller is performed since the possibility of error in the sequence of software steps that can mess up the system so that it needs to restart the process from the beginning. Secondly, the delivery of data, this is done to start sending the measurement data to the smart phone. Thirdly, changing the sampling time of data recording of temperature and RH, it does not always take the same sampling during operation.

The application interface was designed in the form of activities that have specific functions in accordance with the existing process. The structure of the application interface is designed as follows:

1. Main Menu: provides the option of accessing other provided activities.
2. Display Table: displays the measurement results in a table view.
3. Graphic Display: displays the measurement results in a graphical display.
4. Set Time Sampling: sets the sampling time data recording
5. Help: details explanation of features, applications, and how to use the software.

The proposed system has been developed by using SQLite database built automatically by the application processing text (i.e. SMS) from the default Android smart phone. Telemetric measurement system will call messages that have been saved to default database message processing application. When a message in the phone contains the measurement data of temperature and RH, the data will be intercepted from entering the default message inbox processing applications. The data is then processed by using Array Adapter, as one method to put the data into the array in Java programming, and displayed using a component data viewer on Android List View. At the table view activity, the receiving data will be processed into a graph using Achart Engine as extension library to build graphs on Android programming using Eclipse integrated development environment (IDE).

3. Results and Analysis

3.1. Laboratory Scale Test

Sensors-testing was carried out by comparing the sensor measurement value generated by the sensor of the measuring instrument Digital Thermo-Hygrometer as the reference. In the telemetric system, it has LCD display on site location. Figure 2 shows one result of the activities displayed by the 2x16 LCD. Measurements were done by taking 20 samples in different time. The first line on the LCD shows the temperature measured by each sensor (i.e., SHT11 and LM35), while the second line shows the RH measured by sensor SHT11. Digital Thermo-Hygrometer used has two sensors: external sensor to measure temperature and internal sensors located inside the casing to measure temperature and RH. For the comparison with LM35, only internal sensors of the Thermo-Hygrometer were taken into account. Temperature and RH values of the internal sensor are displayed on the second and third line on the LCD Thermo-Hygrometer as shown in Figure 2.

Figure 3 presents the temperature measurement using LM35, SHT11, and Thermo-Hygrometer. The data of sensor LM35 close to the standard one, while there are small errors when compared by SHT11. Both of sensors reveal the close trend line in temperature measurement. There are several factors that lead to gap or error in temperature value of sensor SHT11 against measured by Thermo-Hygrometer as the reference. The greatest error was 1.68 °C (at the 7th sample in Figure 3) and the smallest is 0.08 °C (at the 17th and 19th samples). Temperature value of sensor LM35 has the closest trend with one measure by Thermo-Hygrometer. The highest error was at the 12th sample, i.e. -1.46 °C, and the smallest was 0.02 °C (at the 6th and 20th samples). Mean errors of temperature were repectively -0.317 ^{o}C using LM35 and 0.932 ^{o}C using SHT11. While, its mean squared errors were repectively 0.373 ^{o}C using LM35 and 1.117 ^{o}C using SHT11.

Figure 2. Data Comparison between the telemetric system and the reference

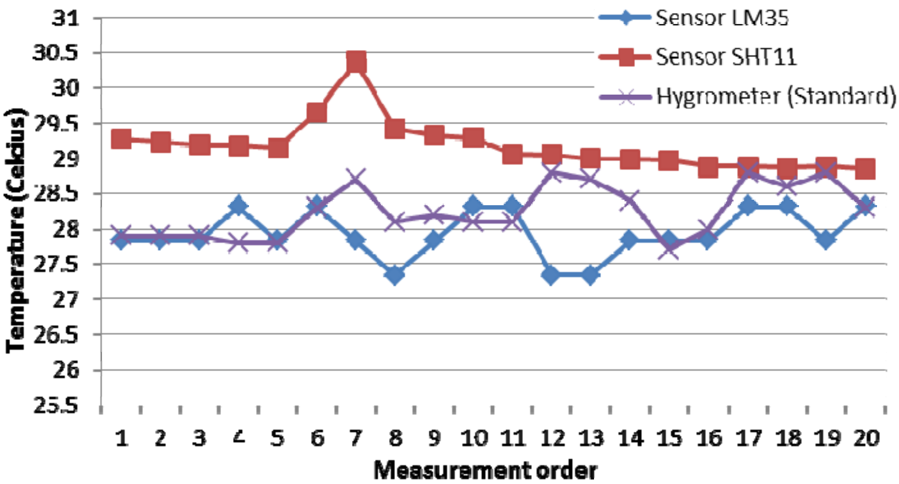

Figure 3. Temperature sensor values with LM35 and SHT11 compared with the standard

The RH measurement test using SHT11 and Thermo–Hygrometer as reference can be seen in Figure 4. The trend line of the measurement data with 20 samples shows the similarity with small errors at some samples. The highest gap (i.e. 2.9%) can be seen on the fifth sample, while the smallest error was 0.13% on the 12th sample. Mean error and mean squared error of RH using SHT11 were repectively 1.378 % and 2.629%.

Furthermore, a laboratory scale testing of the telemetric system including its performance were done by recording the data 2x24 hours without being interrupted by a request from any smart phone. The sampling time was set one minute for each recording process of the data. The testing was performed in Control Engineering laboratory, department of electrical engineering, Tanjungpura University, Pontianak. The recorded data using SD Card located in LOGGING.TXT file was then sketched into a graph on the smartphone as depicted in Figure 5. The highest RH measured was 73.15% and the lowest was 41.87 %. The highest temperature measured from the sensor SHT11 was 31.77 °C, while the lowest was 26.14 °C. For the sensor LM35, the highest temperature measured was 31.25 °C and the lowest was 24.41 °C. From the graph, it can be concluded that the data recorder on telemetry devices can work well in data recording temperature and RH to SD Card with data recorded as many as 2,696 lines with file size 97.4 KB. The SD card will have an automatic eraser for the oldest data once it reaches its limit.

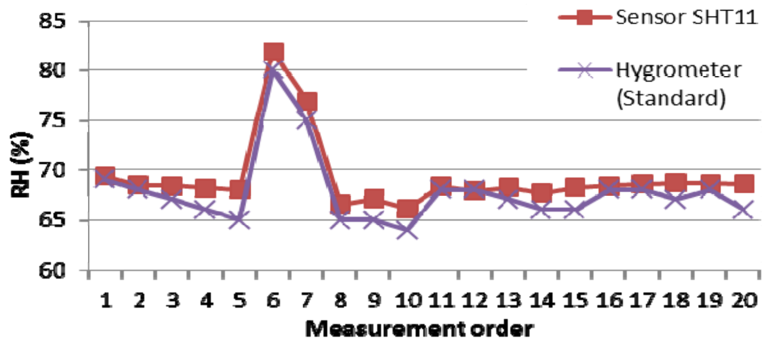

Figure 4. RH sensor values with SHT11 compared with the standard

Figure 5. Temperature and RH measurement in laboratory environment

3.2. Telemetric Measurement System at Anaerobic Digester

The built telemetric measurement device has been tested for its ability to record data on temperature and RH in an anaerobic digester. The anaerobic digester is a waste material degradation or processing of organic waste, manure, or food scraps without involving oxygen or in anaerobic condition, but with the help of anaerobic bacteria. Anaerobic digesters used in the case study of this research are used to produce methane gas, generally known as biogas. LM35 temperature sensor is used to determine the temperature of fermentation that occurs in the anaerobic digester. The conditions of the environment are measured is the ambient temperature and RH of the environment surrounding the anaerobic digester, SHT11 sensor is used to determine the value of the physical parameter.

Telemetry devices placed on the anaerobic digester, and the LM35 temperature sensor is placed inside an anaerobic digester, placement of equipment and sensors can be seen in Figure 6. Protective casing was used to protect the device from rain and weather. It was equipped with air duct of the tube so that the temperature and RH around the digester can be restrained by the sensor SHT11.

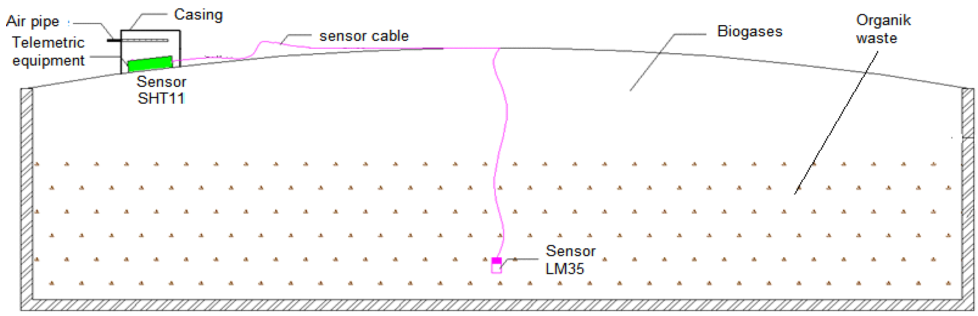

Figure 6. On-site Location of Telemetric Measurement at Anaerobic Digester

The sampling time was one minute data recording without being interrupted by a request for data from telemetry applications on Android phones. Data was extracted from the file LOGGING.TXT. In CONFIG.INI file, sampling time and the mobile number is determined. On the smartphone, the displayed data sample can be set to show the last 10 or 30 minutes measurement (cycle time). Figure 7 shows the graphical representation of the recorded data of temperature and RH. The highest RH was 94.27% and the lowest one was 55.12%. Maximum ambient temperature was about 34.09 °C and the lowest 24.6 °C. The temperature in the digester was in range 22.95 °C to 37.11 °C. Figure 7 shows an example that the autonomous telemetric data measurement can work properly in recording temperature and RH. For the two days recorded data, the recording file size was 94.4 KB with 2,615 rows of data on the measured temperature and RH.

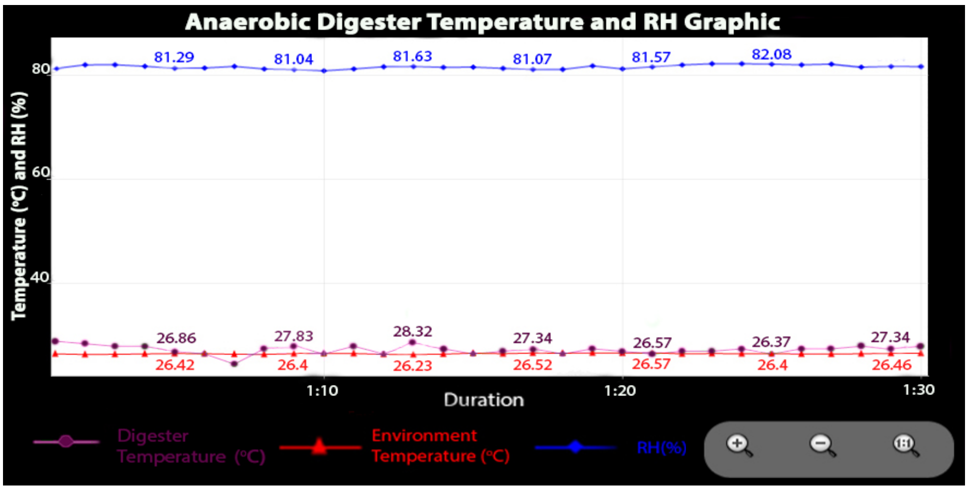

Figure 7. Real-time Temperature and RH measurement at the digester using a smart phone

3.3. Electrical Energy Consumption

Measurements of the electrical energy consumption were taken in various states of telemetry devices: standby, recording/reading data from or to SD card, and receiving commands/transmitting data via the modem. A standby state is a condition when no read/write data to the SD Card and nor receiving commands/transmitting data via the modem during both of these devices is connected to the telemetry system. Power consumptions which had been measured are as follows: 615.2 mW (standby state), 696.6 mW (SD card operating), and 809.5 mW (modem operating). Assuming the use of electrical energy for one hour was when the sampling time was set one minute and within an hour there was a demand for measuring data for a 30-minute cycle time. It was also assumed when writing data, the SD card operated for 1 second, and the time required to send data to the smart phone for a 30 minutes cycle time by 1 minute sampling time was 2 minutes, then it could be calculated the total consumption of electrical energy telemetry devices for one hour as follows.

The result shows that Android-based smartphone can be used as low-cost telemonitoring system which keeps providing accurate and precision data. Compared with non-Android based system presented in [8], although it is commonly used system, the web-SCADA system needs web-server, DC-bus and also other communication infrastructure that make this system need higher capital budget and the further development limited to the particular software designer. In this paper, the proposed system is very low-cost, since it used the available communication infrastructure, without server, and used the available daily smartphone where almost everybody has. While, compare to other Android-based system, currently there is no application of similar system for anaerobic digestion process has been published. Generally, in terms of communication infrastructure, some previous works lacked on communication distance such as in [12] using WLAN and [13] using Bluetooh. Other Anroid based, although using the GSM infrastructure [14], but it still needs server, which may be complicated and costly for small or medium application in developing countries. Moreover, accuracy and precision were not discuseed yet mostly in the previous paper. By this reason, an alternative technology, proposed in this paper, provide more efficient telemonitoring system compared to the previous ones, by maintaining the accuracy and precision.

4. Conclusion

This paper has been described a developed autonomous telemetric measurement data application using smartphone based on Android OS in order to ease monitoring and supervision of renewable energy system such as biogas producer, i.e. anaerobic digester. Android-based telemetry systems provide a convenience way and low-cost technology in monitoring the process measurement data of temperature and RH in an anaerobic digester. Telemetry applications presented in this paper worked properly where the application could display the data stored in the application database to display informative graphs and also table as raw data. Besides, data recorder worked well in recording the data at the temperature and RH measurement locations. The modem also worked well in receiving the command code of the phone as well as in sending data to the smart phone with a low energy requirement. This system is recommended to be used in order to ease the analysis process of the anaerobic digestion for bio-energy production with a low cost telemetric measurement system.

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References

[1] Xuan J, Leung MKH. Leung DYC, Ni M. A review of biomass-derived fuel processors for fuel cell system. *Renewable and Sustainable Energy Reviews*. 2009; 13(6-7): 1301-1313.

[2] Gu W, Li C, Gu M. *Study on the Wind/Biogas Integration System for Power Generation and Gas Supply*. World Non-Grid-Connected Wind Power and Energy Conference. 2009: 1-4.

[3] Sitorus B, Sukandar, Panjaitan SD. Biogas Recovery from Anaerobic Digestion Process of Mixed fruit Vegetables Waste. *Energy Procedia*. 2013; 32: 176-182.
[4] Wolf C, McLoone S, Bongards M. Biogas Plant Control and Optimization Using Computational Intelligence Methods. *Automatisierungstechnik - De Gruyter*. 2009; 57(12): 638-649.
[5] Statistica. Global market Share of Leading Smartphone Operating Systems in Sales to End Users from 1st Quarter 2009 to 3rd Quarter. 2015.
[6] Panjaitan SD, Yandri, Sukandar, Sitorus B. Migration from Gasoline to Gaseous Fuel for Small-scale Electricity Generation System. *TELKOMNIKA*. 2013; 11(1): 29-36.
[7] Panjaitan SD, Yandri, Sukandar, Sitorus B. Comparative study of electricity generation fueled by gasoline, liquefied petroleum gas and biogas from municipal solid waste. *International Journal of Electrical and Computer Engineering (IJECE)*. 2013; 3(6): 762-769.
[8] Soetedjo A, Nakhoda YI, Lomi A Farhan. Web-SCADA for Monitoring and Controlling Hybrid Wind-PV Power System. *TELKOMNIKA*. 2014; 12(2). 305-314.
[9] Dalola S, Ferrari V, Guizzetti M, Marioli D, Sardini E, Serpelloni M, Taroni A. Autonomous Sensor System with Power Harvesting for Telemetric Temperature Measurements of Pipes. *IEEE Transactions on Instrumentation and Measurement*. 2009; 58(5): 1471-1478.
[10] Niancheng Z, Jingwei Z, Hong G. *An Online Temperature Measurement System Based Wireless Communication Technology*. Proceedings of IEEE International Conference on Power System Technology. 2006: 1-3.
[11] Harnett CK. Open Wireless Sensor Network Telemetry Platform for Mobile Phones. *IEEE Sensors Journal*. 2010; 10(6): 1083-1084.
[12] So-In C, Weeramongkonlert N, Phaudphut C, Waikham B, Khunboa C, Jaikaeo C. *Android OS Mobile Monitoring Systems Using an Efficient Transmission Technique over Tmote Sky WSNs*. Proceedings of the International Symposium on Communication Systems, Networks & Digital Signal Processing (CSNDSP). 2012: 1-6.
[13] Aram S, Troiano A, Pasero E. *Environment Sensing Using Smartphone*. Sensors Applications Symposium (SAS). 2012: 1-4.
[14] Moreira N, Venda M, Silva C, Marcelino M, Pereira A. *@Sensor - Mobile Application to Monitor a WSN*. Proceedings of the Iberian Conference on Information Systems and Technologies (CISTI). 2011: 1-6.
[15] Ai W, Chen C. *Green House Environment Monitor Technology Implementation Based on Android Mobile Platform*. Proceedings of the International Conference on Artificial Intelligence, Management Science and Electronic Commerce. 2011: 5584-5587.
[16] Lim W, Torres HK, Oppus CM. *An agricultural telemetry system implemented using an Arduino-Android interface*. Proceedings of the International Conference on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment and Management (HNICEM). 2014: 1-6.
[17] Daou RAZ, Aad E, Nakhle F, Hayek A, Borcsok J. *Patient vital signs monitoring via android application*. Proceedings of the International Conference on Advances Biomedical Engineering (ICABME). 2015: 166-169.
[18] Shin KY, Kim TK, Song JS, Jin SO. *Remote blood pressure monitoring using a pulse diagnostic system in TCM and Android-based Tablet PC*. Proceedings of the International Conference on Biomedical and Health Informatics (BHI). 2012: 647-650.
[19] Postolache O, Girao PS, Ribeiro M, Guerra M, Pincho J, Santiago F, Pena A. *Enabling telecare assessment with pervasive sensing and Android OS smartphone*. Proceedings of the IEEE International Workshop on Medical Measurements and Applications (MeMeA). 2011: 288-293.
[20] Wang L, Lee S, Hsiao Y, Hsu C, Lin K. *A portable platform development for Android-based healthcare monitoring*. Proceedings of the IEEE 17th International Symposium on Consumer Electronics (ISCE). 2013: 15-16.
[21] Prabhakara M, Kulkarni V. *Real time analysis of EEG signals on Android application*. Proceedings of the International Conference on Advances in Electronics, Computers and Communications (ICAECC). 2014: 1-4.
[22] Brock FV, Richardson SJ. Meteorogical Measurement System. New York: Oxford University Press US. 2001.
[23] Damián R, Calva RG, Bañuelos M, Castillo J, Quintana S. Meteorological Unit for Didactic Uses (Umud). *Journal of Applied Research and Technology*. 2004; 2(3): 255-260.