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REAL-TIME REMOTE MONITORING AND ALERTING SYSTEM USING LOW-COST IOT PLATFORM FOR ODOR CONTROL SCRUBBERS

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Abstract. *In order to minimize unplanned downtime of plant's equipment, operation and maintenance personnel need to respond quickly to potential problems. This paper presents a technique to enable real-time notifications for operating two existing stand-alone multi-stage wet scrubbers used to eliminate odors in brewing process. The proposed technique is based on the employment of low-cost Internet-of-Things (IoT) platform to implement a real-time monitoring and alerting system for simultaneous operation with existing control systems of the studied multi-stage wet scrubbers. The implemented monitoring and alerting system at field site consists of eight sensor probes, eight temperature transmitters, two analog-to-digital converters with serial I2C interface, and one Raspberry Pi board. The temperature sensors and transmitters and the converters are used for measuring scrubbing solution temperatures and for converting the 4-20 mA transmitter outputs to be available signals for the Raspberry Pi through I2C bus, respectively. The Raspberry Pi is utilized over the Internet for operating as a web server to serve real-time data for remote client computers, for performing as a database to serve historian data for generating daily and on-demand reports, and for sending alert messages to assigned staffs via LINE Notify. Not only critical process data can then be remotely monitored via the web interface in real time, but also critical process alarms can be notified to rapidly respond. Test results verify that the proposed monitoring and alerting system can function correctly.*
Keywords: Brewing process, Odor control, Wet scrubber, Monitoring, Alert notification, Low-cost IoT platform

1. **Introduction.** Odor emission from livestock operations as well as industrial process productions can be a source of private or public nuisance and pollution [1,2]. Residents around these odor emission sources complain for odor nuisance when odor leaks the outside due to inadequate odor removal. Air pollution control system to eliminate or decrease pollutant emissions to acceptable levels is then an essential part of industrial manufacturers due to health and safety concerns [3]. Its continual and efficient functioning is dependent on effective preventive maintenance and performance monitoring. Interrupted and inefficient operations of the air pollution control system may result in violation of air quality and emission standards. To avoid such a situation, operation and maintenance personnel need to anticipate or quickly resolve potential problems in order to maintain the system running as smoothly and efficiently as possible. Recently, a real-time notification system for monitoring critical process parameters of wet scrubbers used for industrial air pollution control has been introduced [4]. This proposed notification system is based on the employment of statistical process control software to automatically generate email and sent to specific recipients when detecting low and high process alarms. Alternatively,

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the air-pollution monitoring systems based on low-cost Internet of Things (IoT) platform have been presented [5,6]. The portable monitor proposed in [5] consists of five sensors for measuring air pollutant concentrations such as carbon monoxide and the ESP8266 module for sending the measured data to store on a cloud storage system. The stand-alone monitoring system proposed in [6] uses the Arduino Uno board for interfacing air quality sensors and the Raspberry Pi module connected with Wi-Fi adapter for transferring the measured values to the cloud. However, we develop this idea in the different way in this article to apply the low-cost IoT platform using Raspberry Pi to providing not only remote monitoring via web application but also alert notification via LINE Notify application in real time for critical process data and alarms of odor control scrubbers in brewing processing at a beer manufacturer in Thailand. The brewing industry is one of significant sources for odor nuisance for creating public nuisance [7].

The remaining part of this article is organized as follows. Section 2 introduces the studied wet scrubbers for control of odors in brewing processing. Section 3 describes the proposed technique for implementation of real-time monitoring and alerting system. Section 4 and Section 5 give the test results and conclusions, respectively.

2. **Studied Wet Scrubbers in Brewing Processing.** The studied beer production process uses malted barley as the major raw materials. Two identical stand-alone multi-stage wet scrubbers are installed to provide the treatment and control of unpleasant odors emitted from wort boiling stage involving boiling and evaporation of the beer wort in a brewhouse. Figure 1 shows a simple diagram of one of two similar wet scrubbers

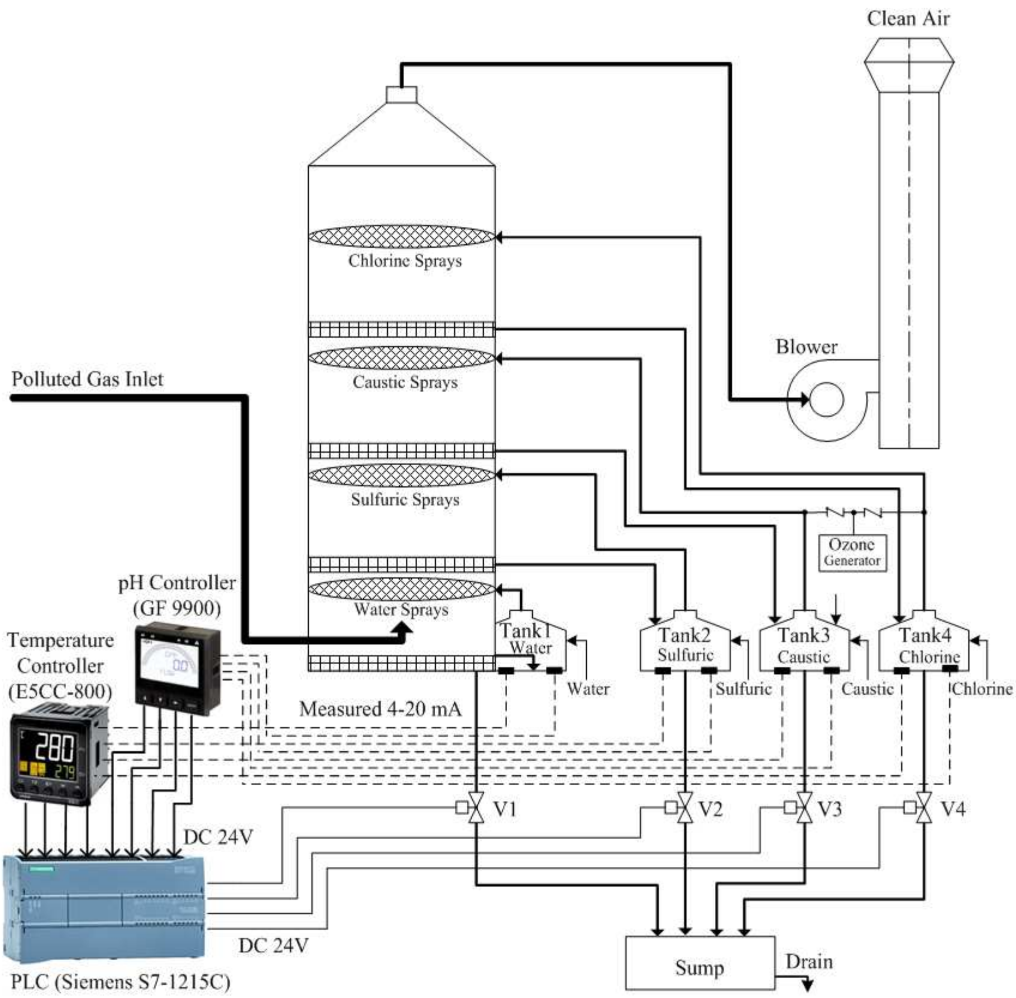


FIGURE 1. One of two identical wet scrubbers for absorbing unpleasant odors

used. Each 4-stage wet scrubber is combined of four different scrubbing solutions (water, sulfuric, caustic, and chlorine) to shift the pH in order for absorbing specific pollutants. The polluted gas stream in the vertical spray tower flows upward into contacts with the scrubbing solution sprays produced by spray nozzles to treat multiple pollutants. The treated air stream is then discharged into the atmosphere through the blower. Each scrubbing solution is being circulated by a recirculation pump. The temperature values as well as the pH values of circulated scrubbing solutions are measured to ensure that the scrubbing solutions are at sufficient strength to absorb the specific contaminated gases. If either the measured temperature value or the pH value is greater than its setpoint, which can be set by the temperature switch (or temperature controller modeled E5CC-800) and the pH switch (or pH controller modeled GF 9900) located on the control panel, then the scrubbing solution with over temperature setpoint (or pH setpoint) will be automatically discharged by opening the outlet valve, and the additional scrubbing solution is added to the tank. Moreover, the temperature and pH alarm lamps and horns located on the control panel will flash and sound, respectively, in case of detecting high and low alarm limits. In the event that all measured temperature and pH values are equal or less than the setpoint values within 8 hours, the scrubbing solutions are also automatically discharged, and the additional scrubbing solutions are automatically filled to the storage tanks. The sequential operations of each wet scrubber are controlled by a Programmable Logic Controller (PLC) modeled Siemens S7-1215C. The control systems of both wet scrubbers are separated from the control systems of beer production process, which are located in a central control room. The operation and maintenance personnel can monitor and interface with the wet scrubber control systems at the field site only through their control panels as shown in Figure 2. This means that the local monitoring at field site can lead to delayed responses to critical process alarms that cause potential consequences.

Figure 2. Control panels of two multi-stage wet scrubbers at field site

3. **Proposed Monitoring and Alerting System.** In order to provide the remote monitoring and alerting in real time to quickly respond to critical process alarms without any negative impacts to the existing automatic control systems of wet scrubbers, the proposed system as shown in Figure 3 is newly implemented for simultaneous operations. Two sets of four Pt100 Resistance Temperature Detector (RTD) probes, four temperature transmitters modeled PR Electronics 4144, and one Analog-to-Digital Converter (ADC) modeled I2C-AI418M are utilized for two studied wet scrubbers. The temperatures of four scrubbing solutions in their storage tanks are specified as the critical process parameters to determine the efficient operations of each wet scrubber. The temperature sensor probes are installed to measure the scrubbing solution temperatures, and the transmitters are used to process the sensor probe outputs for standard 4-20 mA analog transmission. The ADC modules with four input channels are utilized for converting the measured temperature values to be available signals for the Raspberry Pi board through I2C interface bus, which is employed to operate as the PHP web server and MySQL server as well as to support the LINE Notify application. Table 1 gives the parameter tags referred in the proposed system, which are defined as the critical process data to be monitored. Figure 4 shows the flowchart diagram for running the proposed monitoring and alerting system. The measured scrubbing solution temperatures can be displayed on the web application in real time. The daily report of average values of measured temperatures during the 24-hour day can be created, and this report will be sent to the LINE Notify at 8:30 a.m. on the next day of creation. In addition, the on-demand report of average values of historian data during the period from the midnight to the time of request on the same day can also be generated when getting the 'request' command from the LINE Notify. Thus, this useful application for both smartphone and personal computer versions is used for generating the alert notification via chat messages when detecting the critical process alarms,

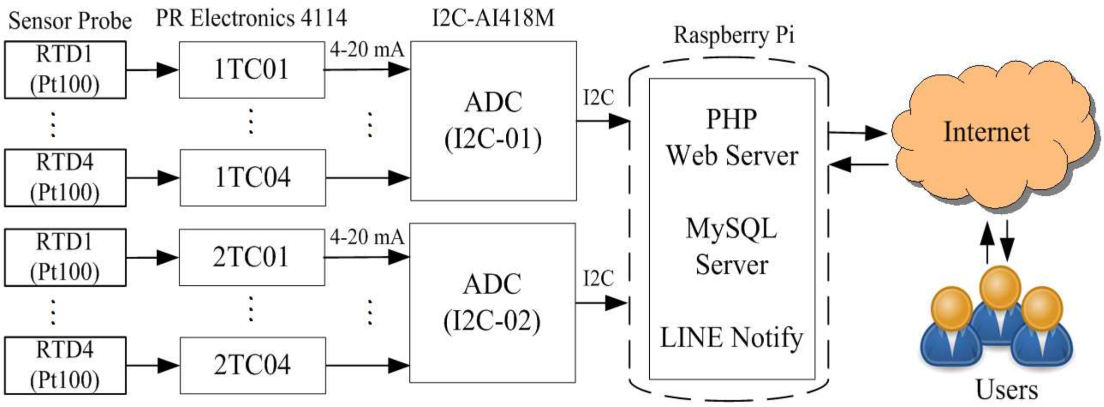


FIGURE 3. Proposed system for remote monitoring and alerting in real time

TABLE 1. Device tags referred in the proposed system

ADC Module	Tag	Description
IC2-01 (Wet Scrubber No. 1)	1TC01	Temperature of the water
	1TC02	Temperature of the sulfuric solution
	1TC03	Temperature of the caustic solution
	1TC04	Temperature of the chlorine solution
IC2-02 (Wet Scrubber No. 2)	2TC01	Temperature of the water
	2TC02	Temperature of the sulfuric solution
	2TC03	Temperature of the caustic solution
	2TC04	Temperature of the chlorine solution

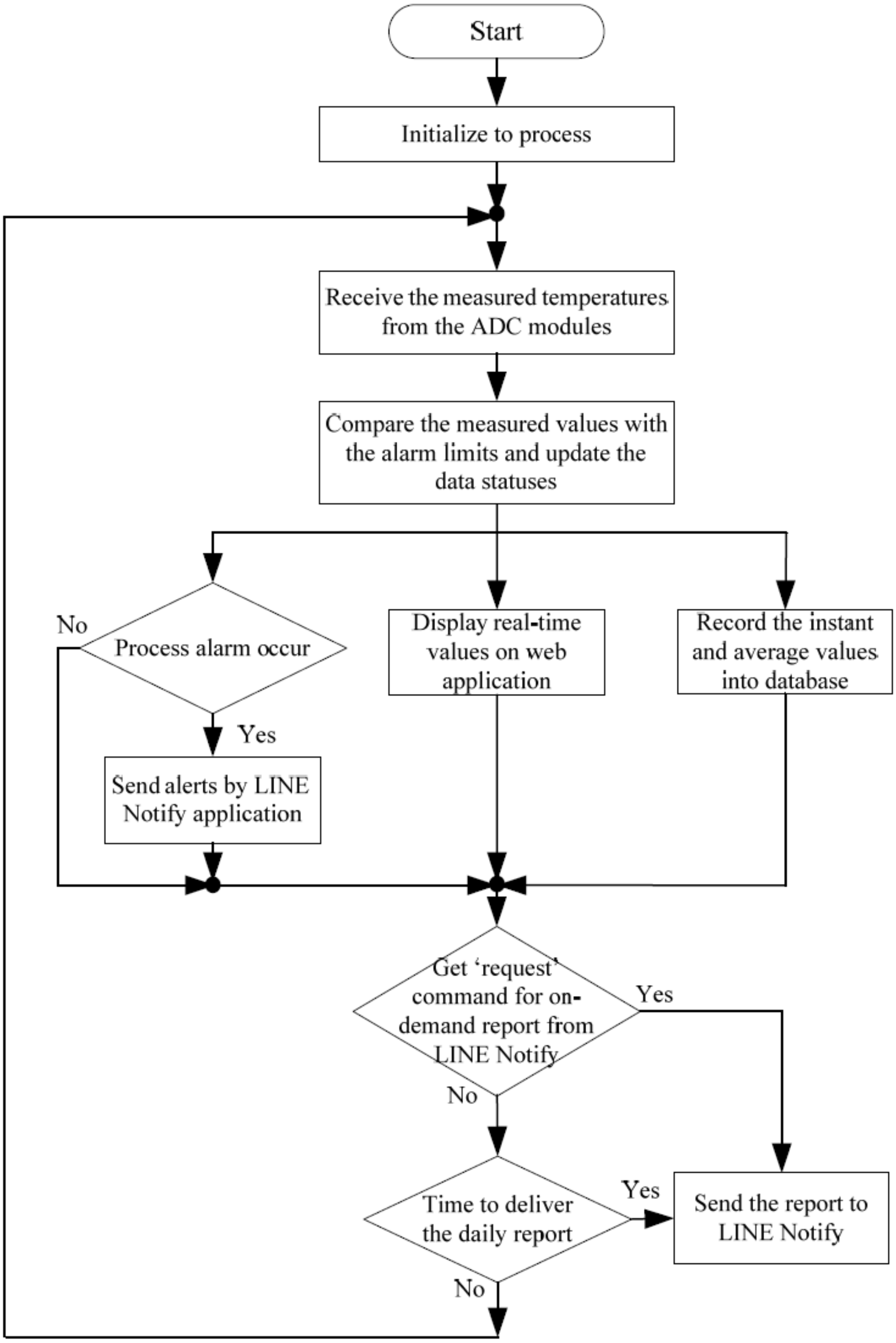
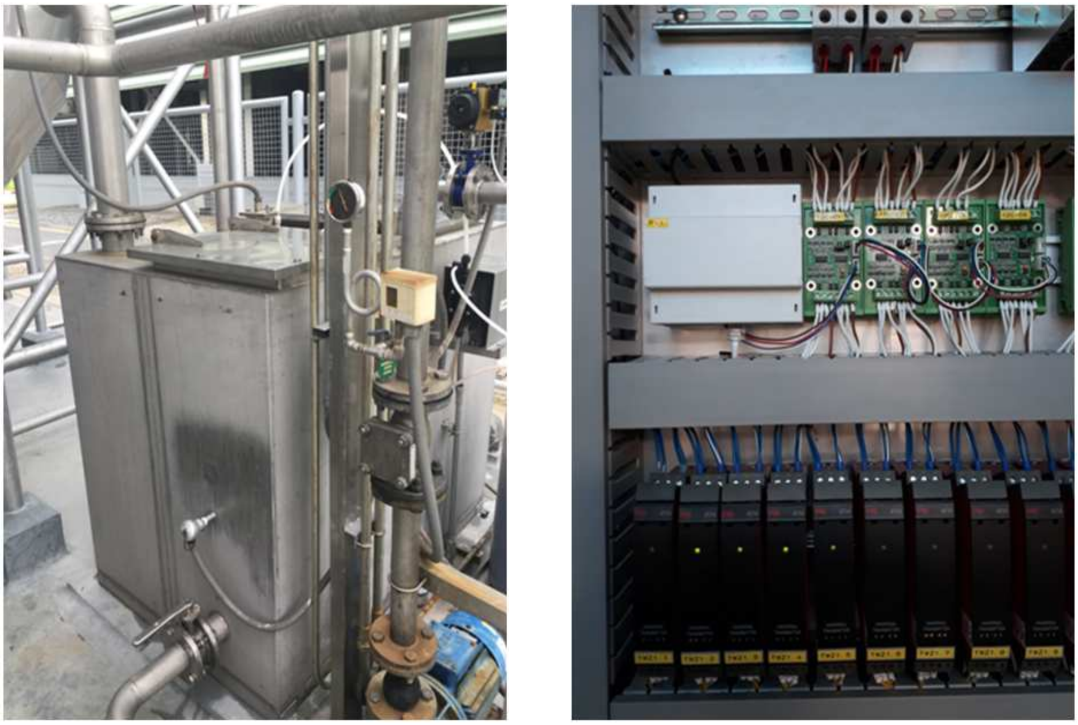


Figure 4. Flowchart diagram for running the proposed system

for sending the 'request' command from one of staff members in the LINE group to obtain the on-demand report message, and for showing both daily and on-demand report messages. At the studied 4-stage wet scrubbers in the beer manufacturer, the proposed system is implemented. Figure 5(a) shows the temperature sensor probe installed at the scrubbing solution storage tank, and Figure 5(b) shows the devices installed in the power cabinet at the field site, which are the temperature transmitters, the ADC modules, and the Raspberry Pi board.



(a) Sensor installed at the tank (b) Devices installed in power cabinet

Figure 5. Implemented system at field site

Figure 6. Display and programming module of the transmitter inside the power cabinet

4. **Test Results.** Figure 6 shows a display and programming module modeled PR 4501 and connected in front of the leftmost temperature transmitter inside the power cabinet, which is temporary installation for direct readout and device configuration during commissioning and maintenance. Figure 7 illustrates the results for testing the MySQL server created in the Raspberry Pi. Figures 8 and 9 show the examples of data recorded in the

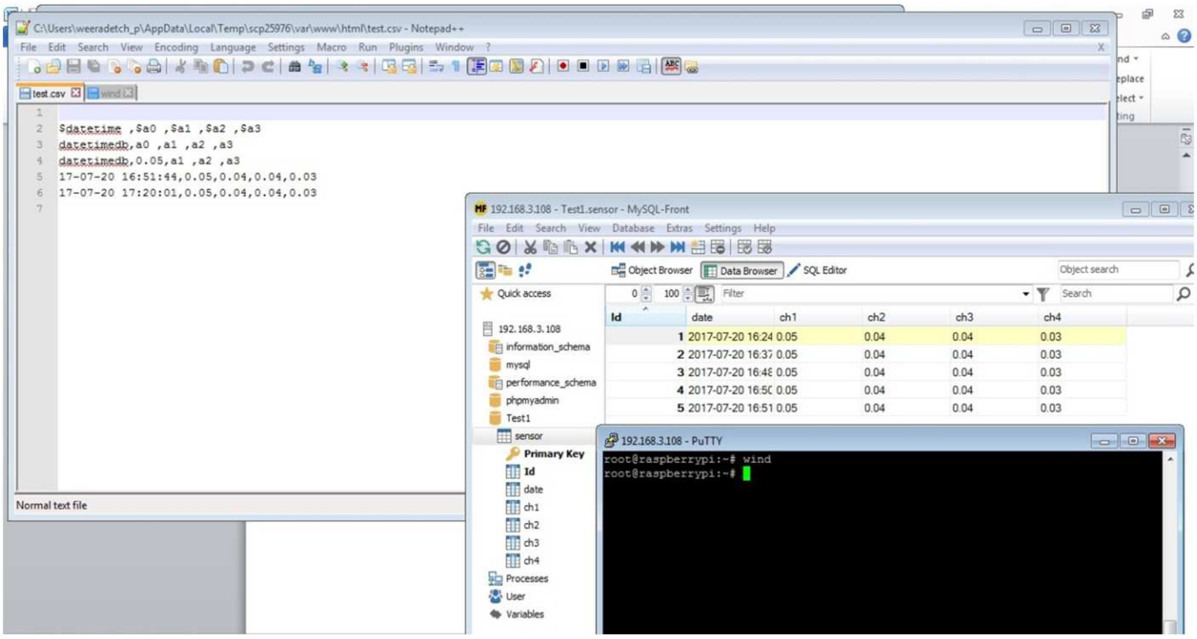
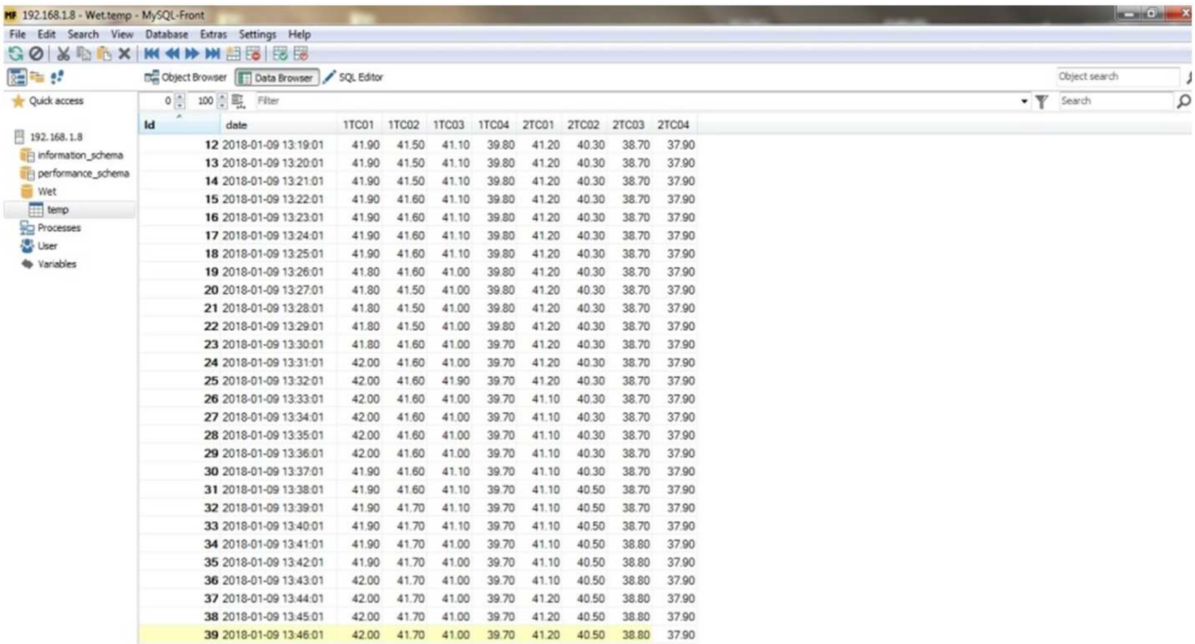


FIGURE 7. Test results of the MySQL server created in the Raspberry Pi



Id	date	1TC01	1TC02	1TC03	1TC04	2TC01	2TC02	2TC03	2TC04
12	2018-01-09 13:19:01	41.90	41.50	41.10	39.80	41.20	40.30	38.70	37.90
13	2018-01-09 13:20:01	41.90	41.50	41.10	39.80	41.20	40.30	38.70	37.90
14	2018-01-09 13:21:01	41.90	41.50	41.10	39.80	41.20	40.30	38.70	37.90
15	2018-01-09 13:22:01	41.90	41.60	41.10	39.80	41.20	40.30	38.70	37.90
16	2018-01-09 13:23:01	41.90	41.60	41.10	39.80	41.20	40.30	38.70	37.90
17	2018-01-09 13:24:01	41.90	41.60	41.10	39.80	41.20	40.30	38.70	37.90
18	2018-01-09 13:25:01	41.90	41.60	41.10	39.80	41.20	40.30	38.70	37.90
19	2018-01-09 13:26:01	41.80	41.60	41.00	39.80	41.20	40.30	38.70	37.90
20	2018-01-09 13:27:01	41.80	41.50	41.00	39.80	41.20	40.30	38.70	37.90
21	2018-01-09 13:28:01	41.80	41.50	41.00	39.80	41.20	40.30	38.70	37.90
22	2018-01-09 13:29:01	41.80	41.50	41.00	39.80	41.20	40.30	38.70	37.90
23	2018-01-09 13:30:01	41.80	41.60	41.00	39.70	41.20	40.30	38.70	37.90
24	2018-01-09 13:31:01	42.00	41.60	41.00	39.70	41.20	40.30	38.70	37.90
25	2018-01-09 13:32:01	42.00	41.60	41.90	39.70	41.20	40.30	38.70	37.90
26	2018-01-09 13:33:01	42.00	41.60	41.00	39.70	41.10	40.30	38.70	37.90
27	2018-01-09 13:34:01	42.00	41.60	41.00	39.70	41.10	40.30	38.70	37.90
28	2018-01-09 13:35:01	42.00	41.60	41.00	39.70	41.10	40.30	38.70	37.90
29	2018-01-09 13:36:01	42.00	41.60	41.00	39.70	41.10	40.30	38.70	37.90
30	2018-01-09 13:37:01	41.90	41.60	41.10	39.70	41.10	40.30	38.70	37.90
31	2018-01-09 13:38:01	41.90	41.60	41.10	39.70	41.10	40.50	38.70	37.90
32	2018-01-09 13:39:01	41.90	41.70	41.10	39.70	41.10	40.50	38.70	37.90
33	2018-01-09 13:40:01	41.90	41.70	41.10	39.70	41.10	40.50	38.70	37.90
34	2018-01-09 13:41:01	41.90	41.70	41.00	39.70	41.10	40.50	38.80	37.90
35	2018-01-09 13:42:01	41.90	41.70	41.00	39.70	41.10	40.50	38.80	37.90
36	2018-01-09 13:43:01	42.00	41.70	41.00	39.70	41.10	40.50	38.80	37.90
37	2018-01-09 13:44:01	42.00	41.70	41.00	39.70	41.20	40.50	38.80	37.90
38	2018-01-09 13:45:01	42.00	41.70	41.00	39.70	41.20	40.50	38.80	37.90
39	2018-01-09 13:46:01	42.00	41.70	41.00	39.70	41.20	40.50	38.80	37.90

FIGURE 8. Data recorded in the created database in the MySQL server

created database in the MySQL server and data displayed on the web application on the client computer in the range of 0-100°C, respectively. The examples of alert notification in case of alarm and clear alarm occurring for the limit of 45°C, daily report message, and on-demand report message by the LINE Notify are shown in Figures 10(a), 10(b), and 10(c), respectively. To confirm the performance of the entire proposed system, Table 2 summarizes two sets of test results of the measured temperatures, which were simultaneously obtained from the direct readout of the display and programming module connected in front of the transmitters (shown in one decimal place), the MySQL server (rounded to the nearest integer), and the web application (rounded to the nearest integer) at the same time. It is evident that the proposed monitoring and alerting system can operate in accordance with the requirements.

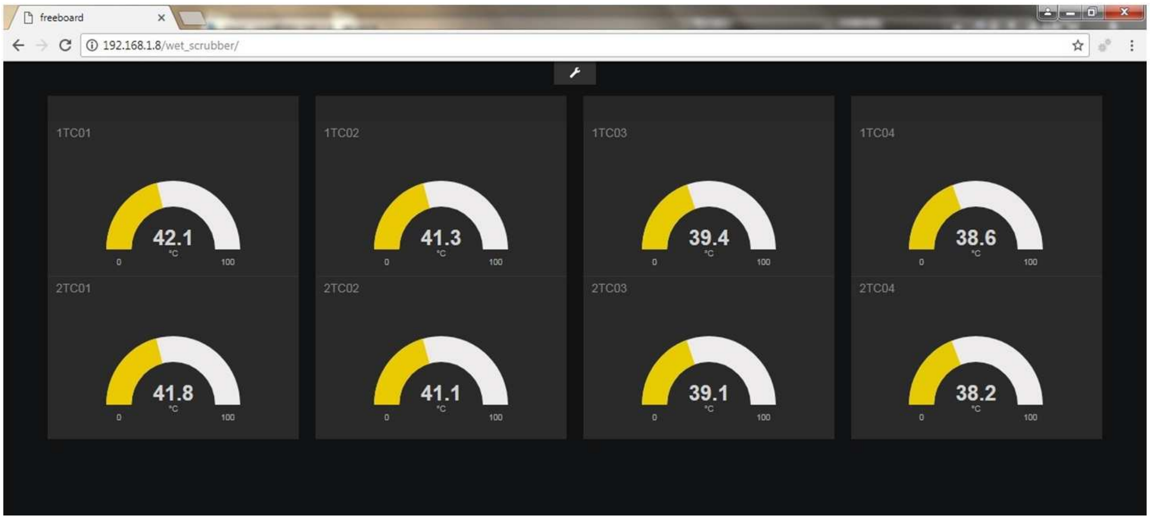
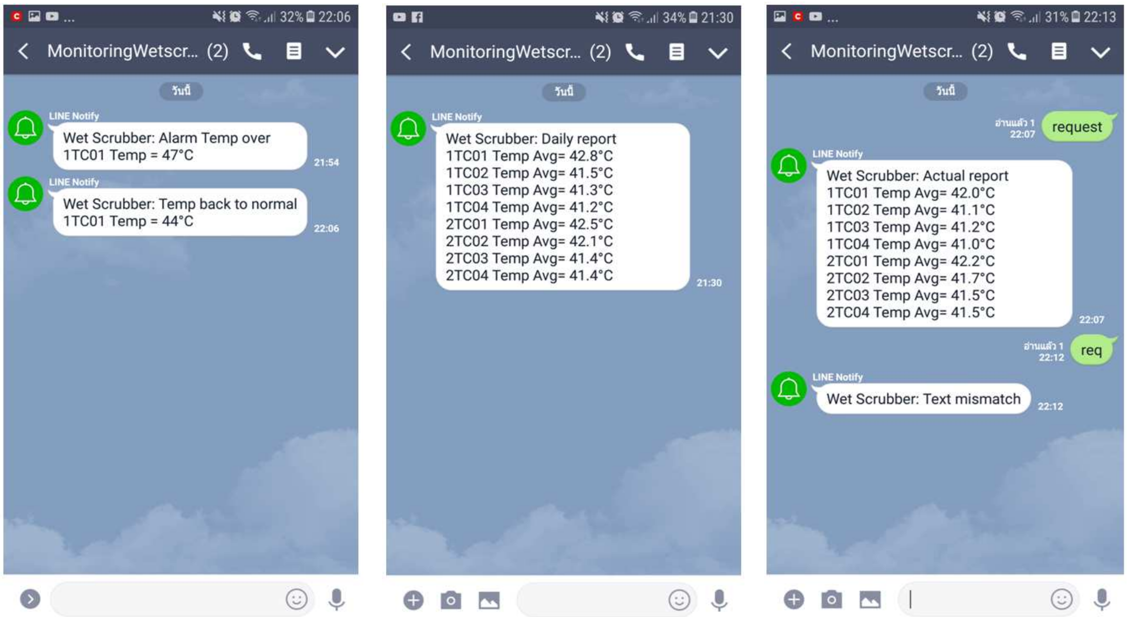


FIGURE 9. Critical process data shown on the web application



(a) Alarm notification (b) Daily report message (c) On-demand report message

FIGURE 10. Examples of alert notification and chat messages using LINE Notify

TABLE 2. Test results of the measured temperatures obtained from the proposed system

Tag	1st Test Results			2nd Test Results		
	Local Display	MySQL Server	Web Application	Local Display	MySQL Server	Web Application
1TC01	34.7°C	35°C	35°C	34.5°C	35°C	35°C
1TC02	33.1°C	33°C	33°C	33.0°C	33°C	33°C
1TC03	32.3°C	32°C	32°C	32.3°C	32°C	32°C
1TC04	32.0°C	32°C	32°C	32.0°C	32°C	32°C
2TC01	35.1°C	35°C	35°C	35.0°C	35°C	35°C
2TC02	34.8°C	35°C	35°C	34.8°C	35°C	35°C
2TC03	33.3°C	33°C	33°C	33.2°C	33°C	33°C
2TC04	33.0°C	33°C	33°C	32.9°C	33°C	33°C

5. **Conclusions.** A practical technique to implement the real-time remote monitoring and alerting system of two stand-alone multi-stage wet scrubbers for odor removal in brewing processing has been presented. The proposed system based on low-cost IoT platform by using Raspberry Pi board for showing the critical process data on web application in real time, for sending alert messages of the critical process alarms, and for creating the 24-hour daily and on-demand reports of historian process data has been described. The monitoring capability limitation of the existing PLC-based control systems of two studied wet scrubbers has been improved by the proposed system. An expansion of using the proposed technique to enable real-time notifications for other industrial plants is the interesting work in future.

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