Human-Machine Interface for Water Quality Monitoring System of White-Legged Shrimp Pond

Baharuddin Aziz[1], Elvayandri Muchtar[2], Farkhad Ihsan Hariadi[3]
School of Electrical Engineering and Informatics
Bandung Institute of Technology
Bandung, Indonesia
[1]baha.bdg@gmail.com, [2]eva_muchtar@yahoo.com, [3]hariadi1981@gmail.com

***Abstract*—In general, this paper proposes the water quality monitoring system in white-legged shrimp ponds with the aim to improve production and cut the cost of maintenance. In particular, it addresses one of the main parts of the system, the HMI. HMI functions to receive data from the RPM measurement. Then, display the values on LCD and status of values whether normal or not by the color of LED. Also, display the status of value with and minus-sign for abnormal condition and plus-sign for the normal condition on LCD. The component condition of HMI represented by LED color. Besides, HMI also stores the measurement results to SD card, and give feedback an alarm signal and SMS if there is a condition that value passes the normal limit. In this paper, the discussion focus lies in the specification, design, implementation, and testing of HMI system. Based on the results of implementation and testing, obtained throughout the components contained in the HMI worked well. They work based on their specifications and design. At the end of the explanation, there is some suggestion for next developments, namely, add more LED on the LED-sensor-board and LED-component-board, improve the received SMS, and provide keypad. Develop algorithms that can adjust date and time manually, handle storing some phone numbers, and manage the SMS sending to those numbers.**

Keyword*—HMI, design, implementation, testing, monitoring system, water quality, white-legged shrimp

I. INTRODUCTION

A. White-Legged Shrimp Farming in Indonesia

White-legged shrimps (*Litopenaeus vannamei*) was initiated a decade after the end of the 1980s in Indonesia and nowadays they are popular in Indonesia. [1] White-legged shrimp need special treatment in the maintenance process. One of the factors needed to be considered to maintain the quality of shrimp farming is a good water quality management. [2] Water quality that meets the conditions are like in Table I.

B. Role of Water Quality Monitoring System

The water quality monitoring system is needed to improve the efficiency, accuracy, and precision of data collected in the long-term environmental changes and record fluctuations within a certain period. In the conventional method, checking the water quality carried out by the qualified human resources that take measurements the water quality parameters. Usually, they are manually taking the water sample and analyze them in the laboratory. [2] On the contrary, the water quality monitoring system can measure water quality parameters in real-time and automatic. The measured data stored into the data logger, so the user can access it at a later date and use it as a reference to maintain the water quality. Comparison the conventional method and water quality monitoring system is in Table II.

Table I – Water quality requirements of white-legged shrimp maintenance [3]

No	Parameters	Unit	Range
1	Temperature	°C	28.5 – 31.5
2	Salinity	g/l	15 – 25
3	pH	-	7.5 – 8.5
4	Dissolved Oxygen, min.	mg/l	3.5
5	Alkalinity	mg/l	100 – 150
6	Organic materials, max.	mg/l	55
7	Total Ammonia, max.	mg/l	0.01
8	Nitrite	mg/l	0.01
9	Nitrate, max.	mg/l	0.5
10	Phosphate, min.	mg/l	0.1
11	Water level	cm	120 - 200
12	Water turbidity	cm	30 – 45

Table II – Comparison of conventional method and monitoring system

Parameters	Conventional Method	Monitoring System
Monitoring	Routine visiting every pond at certain times	No need routine visiting the ponds
Frequency of Data Sampling	Once or twice a day, depend on the company	Every minute or some minutes
Additional Features	(not available)	• History data • Warning alarm • Warning SMS

II. WATER QUALITY MONITORING SYSTEM

This section will summarize some previous works about water quality monitoring system.

- Wiranto et al. [2] proposed an integrated online water quality monitoring system. It applied specifically to monitor DO and pH parameter in several shrimps aquaculture centers in Indonesia. Their aim was to reduce energy consumption and create optimum water condition for shrimp aquaculture. They use an automatic aeration system.
- Lieping et al. [4] proposed the solution for problems that existed in wired water monitoring, such as high cost and restricted monitoring water range.
- Prasad et al. [5] proposed a smart water quality monitoring system for Fiji, using IoT and remote sensing technology.
- Alkandari et al. [6] attempted to deploy sensors of the network which is used to monitor water characteristic on the sea surface. Those characters are temperature, pH, DO, etc. Then, they provide various convenient services for end users who can manage data via the website from long distance or applications in a console terminal.
- Perumal et al. [7] proposed an IoT that measured water level based on water monitoring system in real time. It based on

978-1-5090-3840-4/16/$31.00 ©2016 IEEE

an idea that the level of the water can be very important parameter when it comes to the flood occurrences.

Compared to them, this paper proposes water quality monitoring system in white-legged shrimp ponds with the aim to improve production and cut the cost of maintenance. In particular, it addresses one of the main parts of the water quality monitoring system, Human-Machine Interface (HMI).

III. System Specification

A. Block Diagram and Function of Monitoring System

Level 0 design and diagram block of the system are like in Fig. 1 and Fig. 2 which description is in Table III.

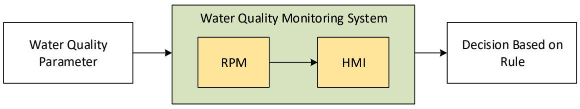

Fig. 1 Level 0 design of monitoring system

Table III – Description of level 0 design

Parameters	Description
Input	Water quality parameter, like temperature, pH, DO, salinity, and turbidity.
Output	The decision of system based on the rule, viz. turning on the alarm or sending SMS.
Function	Remote Pond Monitoring (RPM): • Collecting all of the water quality parameters and send them to HMI. Human Machine Interface (HMI): • Receiving data from RPM • Process the data received from RPM • Display processed data • Give feedback (alarm sound or sending SMS)

HMI has the following functions.

- Receive measurement values from RPM.
- Displays the values on the LCD.
- Storing the values to the SD card.
- Displays the value status whether normal or not by:
  - The color of the LED, and
  - minus-sign or plus-sign on the LCD.
- It displays the condition of HMI component by LED color.
- Give feedback alarm signal and sending SMS if there is a condition that parameter value passes the normal limit.

B. Physical and Environment Requirement of HMI

HMI need a case that can protect its component inside caused by humidity and salinity in the air around the coast. The entire vital electronic components such as MCU, GSM module, receiver, and the heatsink placed inside the case. HMI has approximately length 10 cm, width 30 cm, height 40cm, and weight 1-2 kg.

Environment requirement of HMI, namely temperature around 20-40^{o}C, pressure around 1 atmosphere, and humidity around 50-95%. HMI is a static module, so it does not need protection from shock and vibration.

HMI use 220V AC power as a source; it will regulate become 12V using 12V5A switching power supply and distributed to components that need a 12V source, namely fan. Then, second regulation 12V to 5V using DC-DC converter and distributed to components that need a 5V source, namely MCU, RTC, SD card module, receiver, relay, LEDs, GSM module, and LCD.

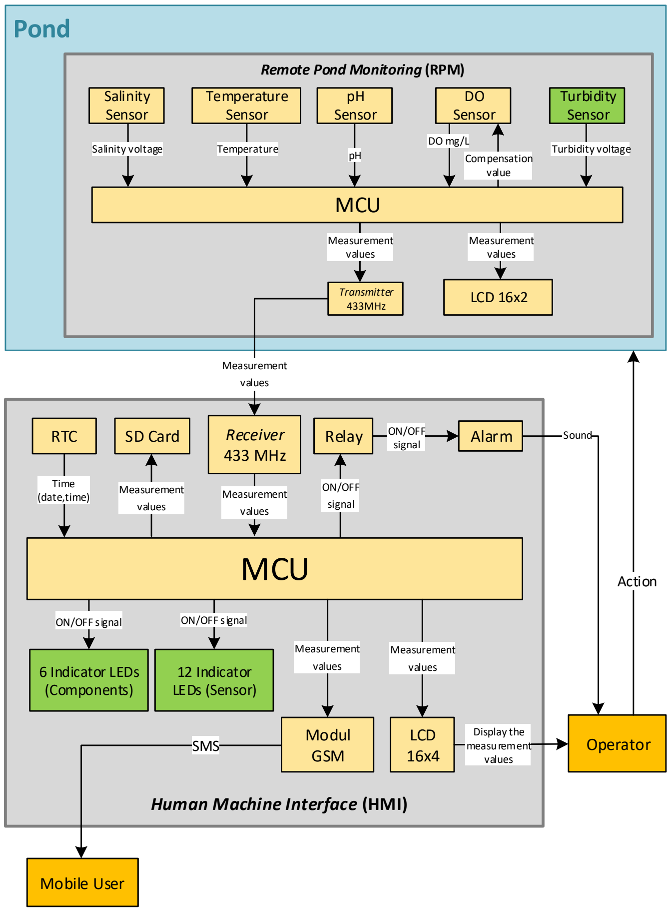

Fig. 2 Diagram block of water quality monitoring system

C. Hardware Specification of HMI

Based on the physical and environment of HMI, these are the hardware specifications.

- The switching power supply as a first voltage converter.
- DC-DC converter as a second voltage converter.
- HMI use MCU that can accommodate several components.
- Receiver module used to receive data from RPM.
- LCD that can display quite a lot of information because there are five parameters.
- LEDs used as a sign of a different condition.
- SD card used to store values received from the RPM.
- SD card module used as a media liaison between MCU and SD card.
- The alarm that emits enough sound to a radius 50-100m.
- GSM module which can be used to send SMS.

D. Software Specification of HMI

Beside hardware specification, also need to explain the software specification, namely:

- RTC set the correct date and time based on local time.
- Checking the files in the SD card which one-year-old, then remove them.
- Making log files of recorded values every day.
- HMI always receives data from RPM at a certain delay.
- LCD always displays values from RPM, date, and local time.

IV. HARDWARE DESIGN OF HMI

After determined the specification of HMI system, these are its hardware design.

- Switching-power-supply 12V5A as a first voltage converter.
- DC-DC converter 12V-5V as a second voltage converter.
- HMI use Arduino Mega 2560 microcontroller board because it has 54 I/O digital pins. [8] Those pins needed because there are many components used in the HMI.
- HMI use 433MHz receiver-module because the frequency used by the transmitter module in RPM is 433MHz. Besides, the module is relatively cheap and available in the market. Using this frequency need permission from the government. In Indonesia, frequency 433Mhz is for amateur radio location. [9] Therefore, the user need follow ministerial regulation, namely [10]. There is some condition that allowed to using certain frequency in Indonesia, namely:
  - transmit power below 10mW,
  - operated at 2 400 – 2 483.5 MHz, 5 725 – 5 825 MHz, or
  - categorize as Short Range Devices (SRD).
- HMI use LCD 16x4 because there is many information, namely five parameters, date and time, and components status (whether normal or not) of the HMI.
- There are two groups that require parameter status, namely:
  1. the condition of the components of the HMI; and
  2. the condition of the water parameter value (whether normal or not).

  Therefore, HMI use six LEDs for the status of components on the HMI (three green LEDs, one yellow LED, and two red LEDs) and ten LEDs for the condition of water parameter values (five green LEDs and five red LEDs).
- HMI use 2GB SD card because the size of data stored not big enough and one-year-old only.
- The alarm used is a horn siren 12V.
- HMI use general GSM module that has no output jack for microphone or earphone, nor GPS facility.

V. SOFTWARE DESIGN OF HMI

Software design of this monitoring system consists of the main system, LED-Sensor-Board, and LED-Component-Board. LED-Sensor-Board has the function of representing the value condition, whether normal or not. LED-Component-Board has the function of representing the condition of components in HMI. Software design of the main system is like in Fig. 3. In the initial condition, the system does following tasks.

a. Initialize GSM module.
b. The date and time settings.
c. Initialize the condition of the SD card.
d. Initialize the display on the LCD 16x4.

Then, the software design of LED-component-board and LED-sensor-board is shown in Fig. 4 and Fig. 5.

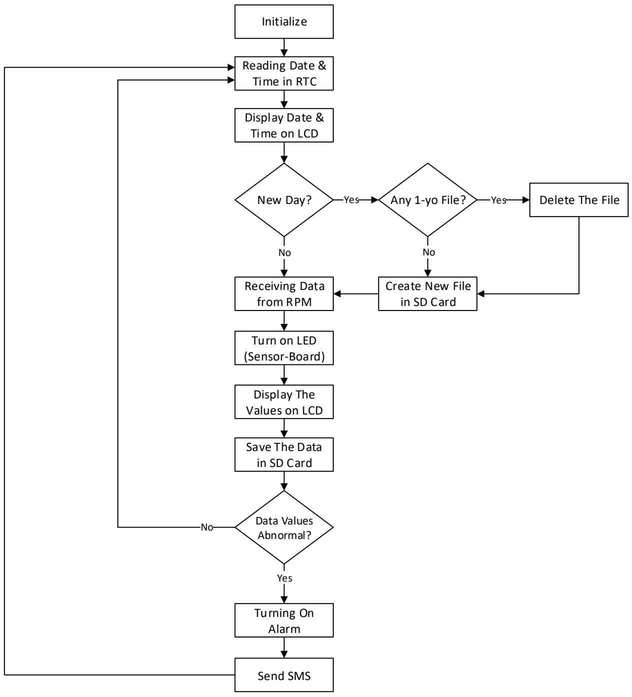

Fig. 3 Software design of the main system

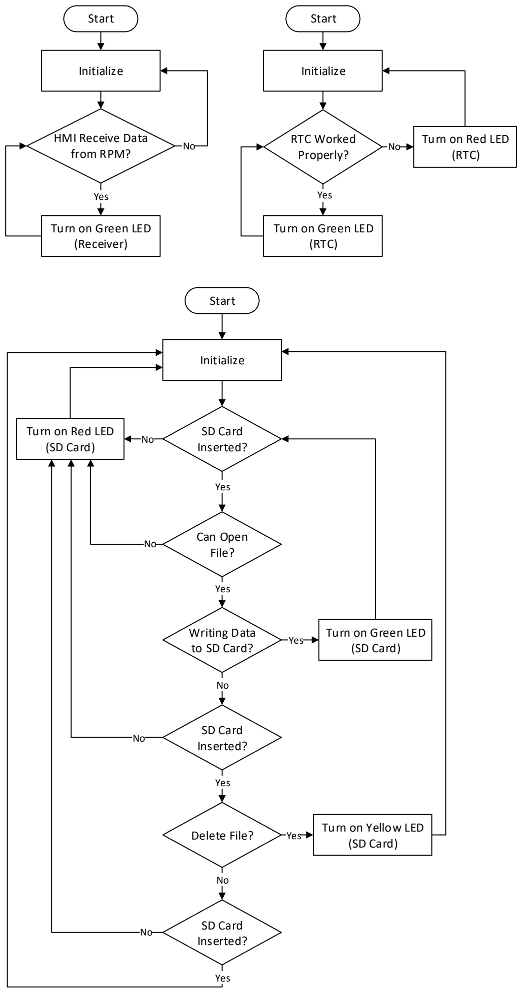

Fig. 4 Software design of LED-Component-Board

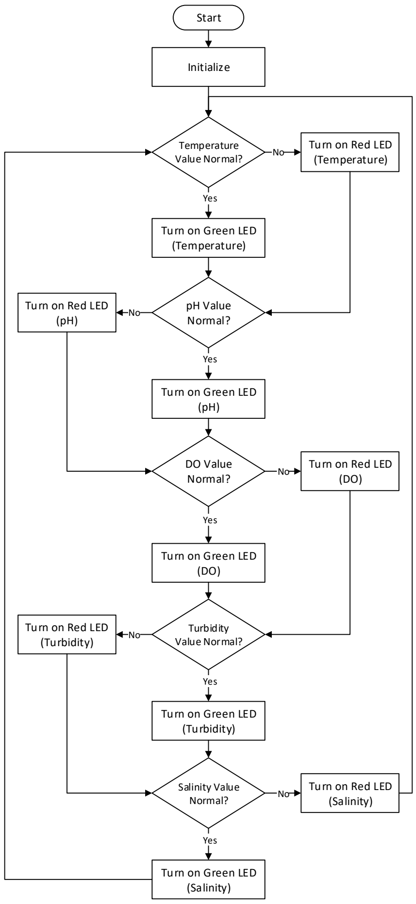

Fig. 5 Software design of LED-Sensor-Board

VI. Testing Result and Analysis

Before test the system, there is an implementation of system design as shown in Fig. 6 and Fig. 7.

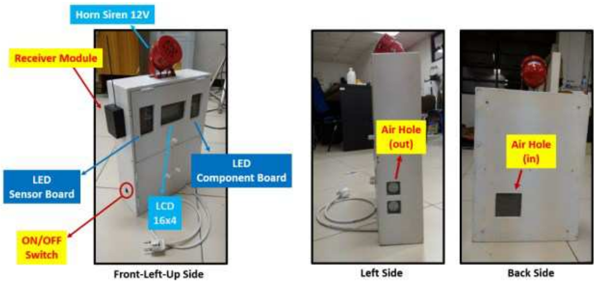

Fig. 6 Implementation of system design (outside)

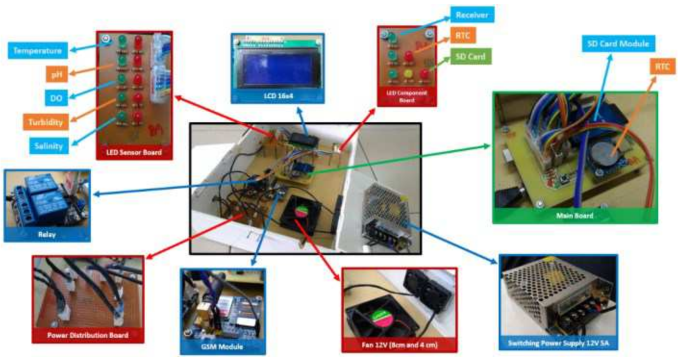

Fig. 7 Implementation of system design (inside)

A. Testing of LED-Sensor-Board

The testing was turning on and off alternately, simultaneously. After that, testing by running algorithms of HMI system. After the test, the result (see Fig. 8) was that LED turns on by the implemented algorithm, namely green LED turns on when values are normal, and red LED turns on when the value is abnormal.

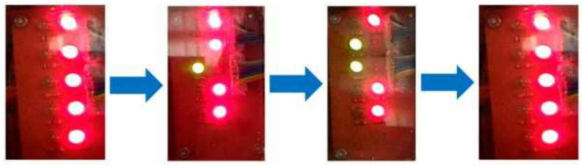

Fig. 8. LED-Sensor-Board testing at HMI

B. Testing of LED-component-board

The test was similar to testing for LED-Sensor-Board, namely turns on and off alternately and simultaneously. After that, testing by running algorithms of HMI system. After the test, the result (see Fig. 9) was that LED turns on by the design of the algorithms applied, namely:

- At receiver indicator LED, green LED turns on when the HMI module receives data from RPM.
- At RTC indicator LED, green LED turns on when the RTC function properly, while the red LED turn on when there is a problem with the RTC.
- At SD card indicator LED, the green LED turns on when the data storage process, the yellow LED turn on when a file deletion process and the red LED turn on when there is a problem with the SD card module.

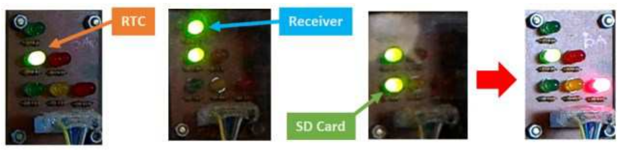

Fig. 9. LED-component-board testing at HMI

C. Testing of Displaying on LCD 16x4

Testing was to apply the algorithm of HMI system with the results shown in Fig. 10.

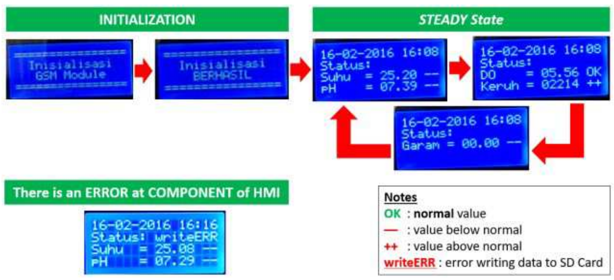

Fig. 10. SD card module in HMI that SD card inserted

D. Testing of Saving File to SD Card

The testing was applying algorithms of HMI system. After testing showed the following results.

- One-year-old file deleted.
- Files containing data logging of parameter values obtained from RPM.

Contents of the file that stored in SD card checked by reading it on the computer; then open the file. The test result was like in Fig. 11.

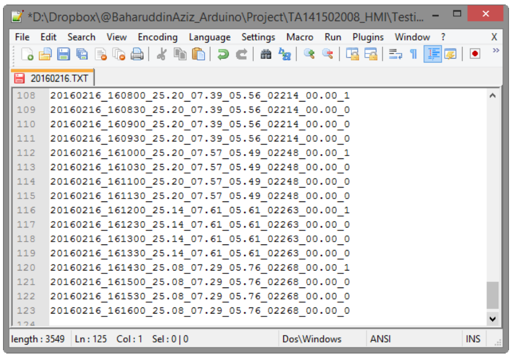

Fig. 11. File content in SD card

In Fig. 11 obtained a collection of numbers that is bounded by an underscore. Explanation of the figure from left-to-right is as follows.

- Eight first characters are YYYYMMDD, means the year, month, and date when the data recorded.
- 10^{th} to 15^{th} characters are hhmmss, mean hours, minutes, and seconds when the data recorded.
- 17^{th} to 21^{st} means the value of temperature.
- 23^{rd} to 27^{th} means the value of pH.
- 29^{th} to 33^{rd} means the value of turbidity.
- 35^{th} to 39^{th} means the value of salinity.
- The number 0 or 1 in the most means a flag of new data received from the module RPM.

E. *Testing of GSM Module*

The testing was applying the algorithm of HMI system. The result was like in Table IV.

Table IV – The test results on the GSM module HMI module

Experiment	Duration	SMS Sent	SMS Received	SMS Not Received	Percentage
3 SMS/5 min	6 hours, 34 min, 30 sec	297	117	180	39,39 %
1 SMS/4 min	1 hours, 51 min, 30 sec	27	16	11	59,26 %
1 SMS/hour	17 hours, 31 min, 0 sec	19	18	1	94,74 %

The SMS print screen on a mobile phone receives an SMS can is like in Fig. 12.

Explanation of the contents of SMS in Fig. 12 was as follows.

- Row 1, means the time of recording data. The format of writing is YYYYMMDD_hhmm, with YYYY means the year, MM means the month, DD means the date, hh means hours, and mm means minute.
- Row 2, the title for SMS, namely *Water Quality Parameter (counter)*. Counter means the order of SMS.
- Row 3–8, label and parameter values from the sensors, which status normal or not, 0 means normal, and 1 means abnormal.

F. *Testing of RTC Module*

The testing was setting the date and time. After these settings, the results displayed on the LCD 16x4 or files on the SD card. The result was in Fig. 10.

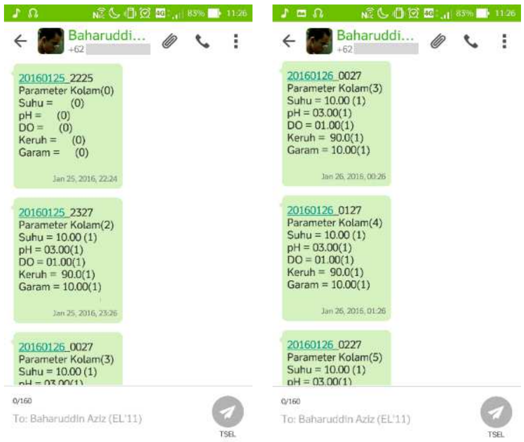

Fig. 12. SMS print-screen received by phone

G. *Testing of Alarm*

The testing was turning on and off the relay. The result was that alarm turned on when relay on and the alarm turned off when relay off. The illustration

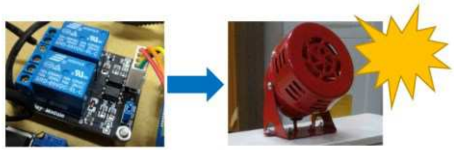

Fig. 13. Relay and alarm in HMI

H. *Testing of RPM-HMI*

The testing was sending and receiving data of water parameter using water that its conditions manipulated until showed the difference of value parameter. The result was like Table V.

Table V – Test result of RPM-HMI using water manipulated

Data Reading in RPM	Display of LCD in HMI	Result of Data Logging
25.2007.3905.560221400.00	16-02-2016 16:08 Status: Suhu = 25.20 — pH = 07.39 — 16-02-2016 16:08 Status: DO = 05.56 OK Keruh = 02214 ++ 16-02-2016 16:08 Status: Garam = 00.00 —	20160216_160800_25.20_07.39_05.56_02214_00.00_1 20160216_160830_25.20_07.39_05.56_02214_00.00_0 20160216_160900_25.20_07.39_05.56_02214_00.00_0 20160216_160930_25.20_07.39_05.56_02214_00.00_0
25.1407.6105.610226300.00	16-02-2016 16:10 Status: Suhu = 25.20 — pH = 07.57 OK 16-02-2016 16:10 Status: DO = 05.49 OK Keruh = 02248 ++ 16-02-2016 16:10 Status: Garam = 00.00 —	20160216_161000_25.20_07.57_05.49_02248_00.00_1 20160216_161030_25.20_07.57_05.49_02248_00.00_0 20160216_161100_25.20_07.57_05.49_02248_00.00_0 20160216_161130_25.20_07.57_05.49_02248_00.00_0
25.2007.5705.490224800.00	16-02-2016 16:13 Status: Suhu = 25.14 — pH = 07.61 OK 16-02-2016 16:13 Status: DO = 05.61 OK Keruh = 02263 ++ 16-02-2016 16:13 Status: Garam = 00.00 —	20160216_161200_25.14_07.61_05.61_02263_00.00_1 20160216_161230_25.14_07.61_05.61_02263_00.00_0 20160216_161300_25.14_07.61_05.61_02263_00.00_0 20160216_161330_25.14_07.61_05.61_02263_00.00_0

Explanation of Table V is as follows.

- Column 1 was data reading in RPM. Data reading was using Serial Monitor of Arduino IDE to saw the data that sent to HMI.
- Column 2 was the display of LCD in HMI. It showed the values received from RPM.
- Column 3 was the result of data logging, which data received from RPM.

Based on the test result of RMP-HMI in Table V, there are some explanations follows.

- Row 1 showed that data that read in RPM was same with data that displayed on LCD in HMI, also same with data stored in SD card (orange-highlight).
- With different value, based on test result in row 2 and 3, it also showed that data read in RPM was same with data displayed on LCD in HMI, also same with data stored in SD card (green-highlight and white-highlight).

VII. Conclusion

Based on the explanation of section I-VI, obtained conclusions HMI is one of the main parts of the proposed water quality monitoring system that receives measurement value from RPM and process them so that HMI can give feedback to the environment. The components in HMI are:

1. MCU, as a central of HMI system setting.
2. Mainboard, as the board liaison between MCU and other components.
3. LED-sensors-board display values status.
4. LED-component-board displays the component status of HMI.
5. LCD 16x4 display the values of water parameters.
6. SD card, store value of water parameters.
7. GSM module sends SMS when values abnormal.
8. RTC set the date and time, then displayed on the LCD 16x4 and SMS.
9. Relay as a module that turns on and off the alarm.

Besides, the design of HMI is implemented and tested which test result are:

1. LED-Sensor-Board, LED-component-board, 16x4 LCD, SD card, RTC, and Relay worked well, means work based on applied algorithm.
2. GSM module function good enough, which results are:
   - 39.39% SMS is received when 3 SMS/5 minutes.
   - 59.26% SMS is received when 1 SMS/4 minutes.
   - 94.74% SMS is received when 1 SMS/hour.
3. Sending/receiving data RPM-HMI worked well, which result is data that read in RPM was same with data that displayed on LCD in HMI, also same with data stored in SD card.

After getting the test result, there are some suggestions for next developments, namely:

1. Add yellow LED on the LED-sensor-board, namely LED for transition conditions, means value near normal and abnormal conditions. The LED used to inform the user for preparing the feedback to the pond.
2. Add more LED on LED-component-board. The LEDs used to inform (more detail) the user about the components in HMI.
3. Improve the succeed percentage of received SMS.
4. Develop algorithms that can adjust date and time manually.
5. Provide keypad for entering a custom phone number and adjusting the date and time.
6. Develop algorithms that can handle storing some phone numbers and manage the SMS sending to those numbers.

VIII. References

[1] Food and Agriculture Organization of the United Nations, "Fishery and Aquaculture Country Profiles: The Republic of Indonesia." [Online]. Available: http://www.fao.org/fishery/facp/IDN/en#CountrySector-ProductionSector. [Accessed: 01-Jan-2016].

[2] G. Wiranto, Y. Y. Maulana, I. D. P. Hermida, I. Syamsu, and D. Mahmudin, "Integrated Online Water Quality Monitoring: An Application for Shrimp Aquaculture Data Collection and Automation," *2015 International Conference on Smart Sensors and Application (ICSSA) Integrated*, pp. 111–115, 2015.

[3] Badan Standardisasi Indonesia, "SNI 01-7246-2006: Produksi udang vaname (Litopenaeus vannamei) di tambak dengan teknologi intensif," 2006.

[4] Z. Lieping, C. Peng, and P. Fei, "Design of Lijiang Water Environment Monitoring System Based on WSN," *2016 Eighth International Conference on Measuring Technology and Mechatronics Automation (ICMTMA)*, pp. 210–213, 2016.

[5] A. N. Prasad, K. A. Mamun, F. R. Islam, and H. Haqva, "Smart water quality monitoring system," *2nd Asia-Pacific World Congress on Computer Science and Engineering, APWC on CSE 2015*, 2015.

[6] A. Alkandari, M. alnasheet, Y. Alabduljader, and S. M. Moein, "Water monitoring system using Wireless Sensor Network (WSN): Case study of Kuwait beaches," *2012 Second International Conference on Digital Information Processing and Communications (ICDIPC)*, vol. 1, no. 4, pp. 10–15, 2012.

[7] T. Perumal, N. Sulaiman, and C. Y. Leong, "Internet of Things (IoT) Enabled Water Monitoring System," pp. 86–87, 2015.

[8] Atmel, "Datasheet: Atmel ATmega640/V-1280/V-1281/V-2560/V-2561/V," p. 22, 2014.

[9] Kemenkominfo, "Lampiran Peraturan Menteri Kominfo No. 29/PER/M.KOMINFO/7/2009 tentang Tentang Tabel Alokasi Spektrum Frekuensi Radio Indonesia," pp. 0–153, 2009.

[10] Menteri Komunikasi dan Informatika Republik Indonesia, "Peraturan Menteri Komunikasi dan Informatika Republik Indonesia Nomor 4 Tahun 2015 Tentang Ketentuan Operasional dan Tata Cara Perizinan Penggunaan Spektrum Frekuensi Radio," 2015.