Design and manufacture control system for water quality based on IoT technology for aquaculture in the Vietnam

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ABSTRACT

In this paper, presents solutions to apply internet of things (IoT) technology in the field of high-tech agriculture and aquaculture in coastal areas of Vietnam, which is currently a new problem. The system includes an application on a smartphone; access parameters via the web, a computer and an IoT control circuit capable of automatically drawing electricity from the solar panel to the energy storage to serve as a source of power for devices (monitoring cabinets). The product has the function of monitoring: water environmental indicators in shrimp ponds (temperature, pH, dissolved oxygen (DO), salinity, redox index at the bottom of oxygen reduction potential (ORP)), on the website 24/24h, and controllable. Automatic control of pump system and DO generator with Inverter technology. The research results in this paper have brought high economic benefits with an automatic water quality control system to improve the productivity and quality of shrimp farming in practice for people in the aquaculture area in Bach Long commune, Giao Thuy district, Nam Dinh province, Vietnam.

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1. INTRODUCTION

Currently, the application of advanced science and technology in the field of agriculture and aquaculture is being focused and developed. In particular, techniques for measuring, controlling, and collecting environmental data remotely are applied in the development of high-tech agriculture to improve production efficiency and ensure the sustainable development of green agriculture steady. The internet of things (IoT) revolution has made significant changes to people's lives now and in the future. With the development of the internet, smart phones (smartphones); computer; electronics and especially sensor devices, IoT is becoming a new trend of the world. Developed countries such as the Netherlands, the US, China, and Korea have been applying new IoT technology to improve the productivity of shrimp and fish farming, bringing high economic benefits and lowering production costs. Products and are not imported from other countries. Besides, it has also brought about a large profit when applying this new technology to aquaculture [1]–[5]. The monitoring of water quality environmental parameters is a very important issue in industry as well as agriculture [5]–[8]. Along with the development of electrical and electronic engineering, IoT-AI technology is developing with interoperability. Almost all new measuring and control devices can now be connected. Through the internet network and overall communication infrastructure bring high economic benefits in shrimp farming, and fish farming [6], [9], [10].

With the development of science and technology, now many enterprises and shrimp farming households in the coastal areas of Vietnam. Nam Dinh province, Thai Binh province, Hai Phong province, Thanh Hoa province, Nghe An province, and Ha Tinh province has applied IoT in aquaculture in general and shrimp farming in particular, helping this industry make a breakthrough from qualitative production to accurate production based on collected data, collect, synthesize and analyze statistics. From depending on weather, climate, farmers can actively adjust parameters (pH, dissolved oxygen (DO), salinity, redox index in oxygen reduction potential (ORP) bottom layer, and pond temperature) to achieve the desired effect. Sensor and measurement equipment systems will be connected to each other, integrated on the basis of IoT technology to monitor, collect data, connect to the cloud infrastructure to retrieve data, analyze and deliver data. Decision making that optimizes water and feed intake, automates daily shrimp health monitoring activities, and provides a real-time monitoring solution. In particular, with the application of IoT to whiteleg shrimp farming, product quality will be improved, thereby contributing to building the product's position and brand, especially export products [11]–[16].

In applications for monitoring control systems that give accurate results with many different control ranges, such as gas quality monitoring systems in pig production using IoT technology, in fish farming (monitoring), monitoring water quality, and pH. As in some research works [8], [14], [17], with only the design of control systems on the basis of theory and connection testing on phones and computers boards, which have not yet been installed and applied in actual production to create real products. Here, the authors have studied and applied practical application to production in large and large ponds >300 square meters, the product has brought high economic benefits to the aquaculture industry in Vietnam [18]–[23]. In this report, we focus on researching and designing a monitoring and control system for water quality monitoring system based on IoT technology application for aquaculture (whiteleg shrimp farming). This system allows to monitor and control the operation of devices through applications on smartphones and computers, including parameters of oxygen generator, pH, DO concentration, pond temperature, salinity, and redox index at the bottom ORP [23]–[26].

2. METHOD

2.1. Modeling and design of shrimp pond monitoring and control system

Consider a system model consisting of ponds described as the control principle of the shrimp farm. The main components are as shown in Figure 1. The main components are as follows: the meter for measuring water environmental indicators (one for each pond), the device using solar electricity from the solar panel and the power converter is put into the monitoring cabinet to store and power the cabinet (make continuous work day and night) without drawing electricity from the grid. The central controller is used to collect data from water environmental indicators from meters at the lagoons and automatically control with inverter technology the DO generator and water pump. The central controller and the meter communicate with each other via wireless WiFi, the central controller can manage up to 247 meters. The central controller sends data to the server computer via WiFi network.

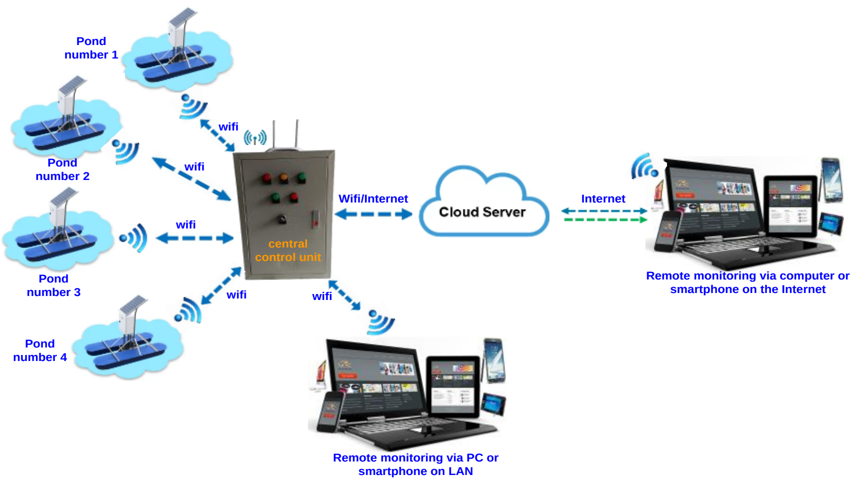


Figure 1. Model of monitoring and control system applying IoT technology

The server computer collects the data and runs the monitoring and control interface. Remote access devices via WiFi local area network (LAN) or the internet to access the monitoring interface such as computers, phones, tablets. The detailed diagram for the central controller and the meter for water environment indicators for a pond is illustrated in Figure 2. Figure 2 shows the measurement of three parameters of water quality indicators. In which the meter performs measurement using sensors to measure the parameters of temperature, pH, DO. The meter uses Arduino Uno R3 microcontroller to measure sensor parameters, shield ethernet W1500 for ethernet communication, and a WiFi repeater to connect to the central station's WiFi [26].

The central controller has two main tasks: collecting water quality parameters from the meter and sending it to the server and automatically controlling the oxygen generator and water pump as Figure 3. The system consists of two electrical cabinets: the central electrical cabinet (Figure 3) can be placed indoors next to the ponds, where the WiFi can be used to link with the monitoring cabinet. The monitoring cabinet is located in the pond to monitor and collect data from the sensors Figure 4.

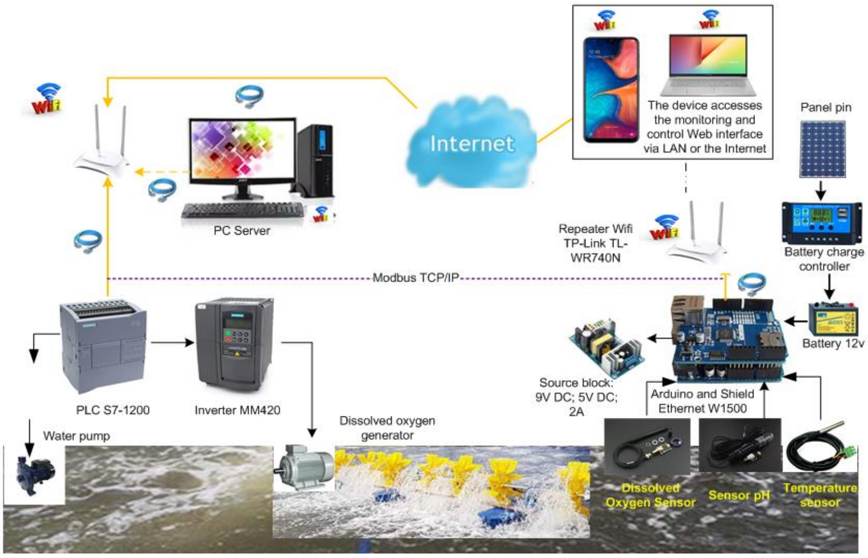


Figure 2. Schematic diagram of the monitoring control system for a shrimp pond

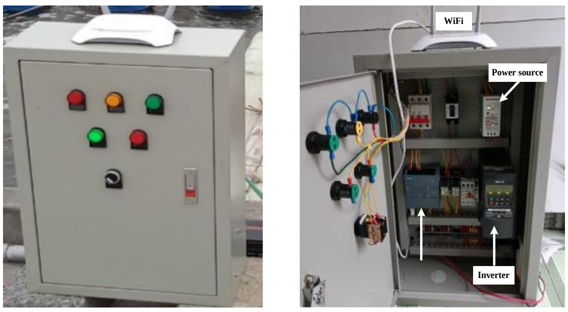


Figure 3. Electrical cabinet for central control

Figure 4. Monitoring cabinet (connecting sensors) meter for measuring water quality indicators

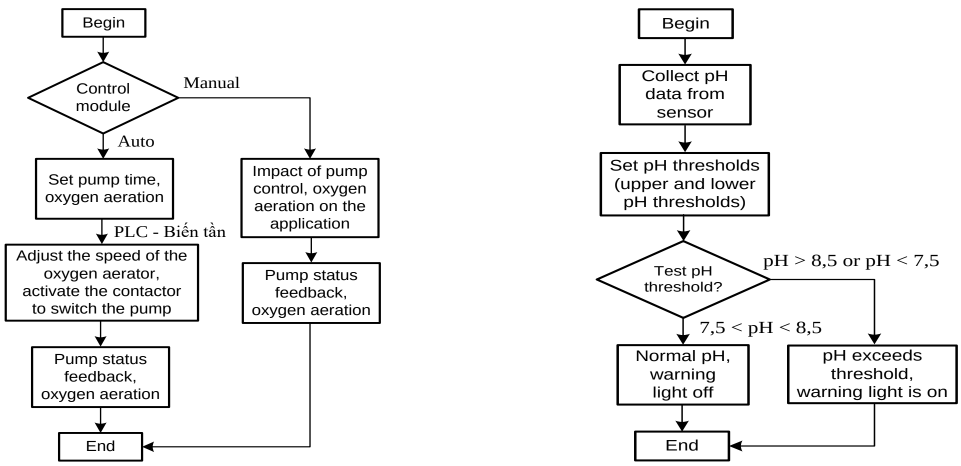
2.2. Build a program to control the pump to generate DO and parameters pH, DO, and temperature

The controller and monitor the operation of the water circulation pump and the oxygen machine in the shrimp pond monitoring control system, including two operating modes. In the automatic mode, allowing users to set the alternate pumping time between pumps and between oxygen machines, and monitor the status of pumps and oxygen machines through the application on smartphones bright. Based on the DO index collected from the meter, the central unit automatically controls it through the proportional integral derivative (PID) controller on the power line carrier (PLC) (with the required amount of DO of 6 mg/l). The PLC provides a voltage signal (0-10 V) to the inverter to control the operating frequency for the DO generator. Based on the salinity index, ORP to automatically control the water change for shrimp ponds [3], [21].

For manual control mode, it is possible to control the pump and oxygen machine by pressing the button and monitor the status of the pump and oxygen machine through the application on a smartphone with the operating system Adrian. The pump with a capacity of 450 W and an oxygen machine with a capacity of

200W are used for the control system to monitor the pond with an area of 300 m^2. Figure 5(a) shows the flowchart of the pump control algorithm; Figure 5(b) system pH supervision algorithm and flowchart of supervisory control algorithm DO, the oxygen machine in the pond is controlled by frequency inverter running fast and slow according to the PID algorithm and running on the PLC S7-1200 platform. The application interface to monitor and control the operation of pumps and oxygen machines for shrimp pond systems will be presented in the research results section.

The pH monitor in the model of monitoring and controlling water quality for ponds is designed with the function of allowing the upper and lower thresholds of pH to be set and warnings when the pH exceeds the allowable threshold. Use the analog pH sensor used to measure the pH and communicate with the central microcontroller board through the pH meter communication board. The pH sensor is connected to the connector located on the pH meter board and the analog signal pin on the pH meter is connected to the analog port of the central microcontroller circuit in the monitoring cabinet. Algorithm flowchart and application interface for monitoring pH in shrimp ponds are presented in Figures 5(b) to 8 [3], [21]. The DO concentration monitor of the monitoring cabinet to monitor and control the water quality for shrimp ponds is designed with a function that allows to set the upper and lower thresholds of DO and give warnings when the DO concentration is low, exceed the allowable threshold. Use the SV1.0 DO sensor to measure the DO concentration in the water. Algorithm flowchart and interface for online monitoring of DO concentration are shown in Figures 6-8. Besides, monitoring water temperature in shrimp pond using Thermocouple sensor RTD PT100.



(a) (b)

Figure 5. Flowchart of monitoring control algorithm (a) for pump system, oxygen machine and (b) for pH monitoring system

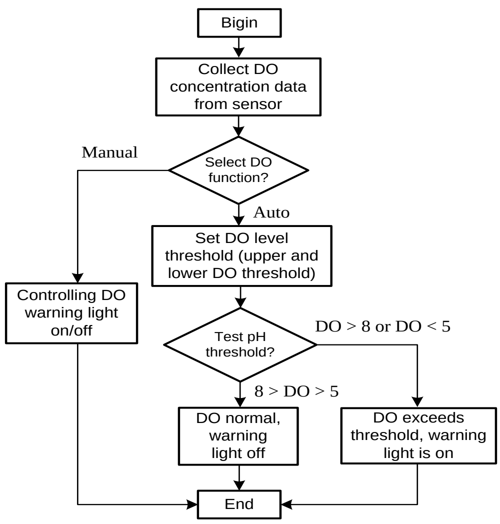
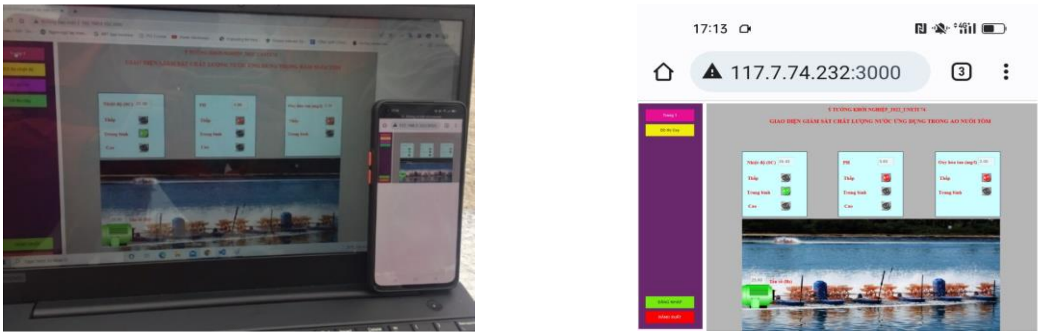


Figure 6. Flowchart concentration control and monitoring algorithm of DO

Figure 7. The interface when accessing from a computer via LAN

3. RESEARCH RESULTS AND DISCUSSION

The from the computational and programming studies as above, the research team gave some monitoring control results on the parameters of the pond on the basis of IoT through the website with the access device being a phone or computer. Server selection group to connect to the internet is a computer with the following IP address: 117.7.74.232:3000 or LAN access 192.168.0.102:3000 with in Figure 8(a) and in Figure 8(b). The monitoring results on the website via a computer as shown in Figure 7, and the monitoring results on the website through the phone as shown in Figure 8. The group has also experimented with product monitoring and control systems in some ponds (300 m^2/1 pond) of hoang hiep aquaculture and breeding company limited (address: team 2, bach long farm area, bach long commune, Giao Thuy District, Nam Dinh province) as shown in Figure 9 to monitor parameters: measure water temperature, measure DO concentration, and measure pH. This has been highly appreciated by businesses for the quality of products that can be measured by the parameters of the pond as above.



(a) (b)

Figure 8. Interface when accessing from phones and computers with internet (a) access via LAN and (b) access via 4G

Figure 9. Deploying and installing monitoring and control system with many shrimp ponds in Bach Long commune, Giao Thuy district, Nam Dinh province, Vietnam

Some measurement results and data collection are at the time of actual testing. The control parameters of the product are achieved: The temperature should be from (18÷33) ˚C. The ideal pH for shrimp ranges from 7.5-8.5 and the best is between (7.5-8.3) pH. DO should reach from (5-7) mg/liter. Salinity to reach: (5÷35) %. The redox index at the bottom of the ORP should be: +150 to +250 mV. The results of Table 1 and Figure 10 (retrieved from computer); here is accessed from time to time as in the following static IP address: 117.7.74.232:3000 or LAN access 192.168.0.102:3000, in the system as shown in Figure 8. In addition, the results in Table 1 and Figure 10 can be viewed directly on the phone with the app installed.

Table 1. The results of measurement of data collection parameters in ponds during one day

No	Measurement time (hh: mm)	Dissolved oxygen sensor (mg/L)	pH sensor	Temperature sensor (˚C)
1	8h:15	5.5	7.64	28.5
2	9h:35	5.8	7.55	28.8
3	10h:05	5.3	7.68	29.6
4	11h:00	5.8	7.42	29.7
5	14h:10	6.6	7.63	29.8
6	14h:30	5.8	7.51	30.5
7	14h:55	6.1	7.66	29.5
8	16h:25	5.9	7.26	28.7
9	16h:45	6.4	7.48	27.7
10	17h:25	6.5	7.71	26.2

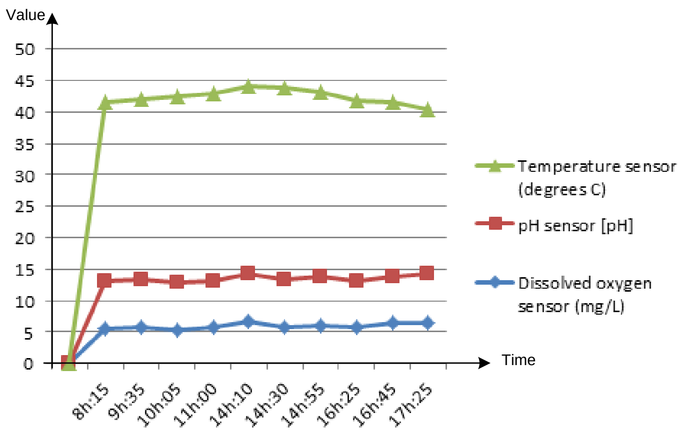


Figure 10. Graph of measured parameters and data collection in ponds during a day

The data is collected continuously from the sensors transmitted to the user application on the smartphone. The parameters in the monitoring control model (pH, DO, and water temperature) are measured by the sensors of the monitoring unit and dedicated meters at the same time to serve as a basis for comparing measurement results. Thereby, it shows that the measured parameters have a negligible difference of small error (0.02%) between the monitor and the dedicated meter. Most of the parameters in the system supervisory control model are within the allowable threshold. In case of parameters exceeding the threshold, the system will promptly warn users to have appropriate treatment plans to ensure stable operation of the pond system and bring high economic benefits to farmers in the aquaculture sector. Compared with previous works [15], [16], [23], [25]. In this paper, the authors have researched and designed a water source monitoring control system for aquaculture in Vietnam; with a system that works in real time and applies to aquaculture households such as shrimp and fish farming.

4. CONCLUSION

This report has studied the monitoring and control system based on IoT technology that has been designed for application in aquaculture model. The system allows monitoring of environmental parameters in shrimp ponds such as pH, DO concentration, water temperature, and at the same time gives an alert when the threshold is exceeded. Besides, the system can be automatically controlled according to pre-set parameters or users can control it themselves by pressing buttons on the smartphone application. The system is designed in terms of hardware and firmware modules and then integrated into a monitoring and control unit. Design user applications on smartphones to use via App and Android operating system. The monitoring and control system is tested in practice at Hoang Hiep aquaculture and breeding production limited liability company (Bach Long commune, Giao Thuy district, Nam Dinh province). Measurement results from sensors of the monitoring and control system are compared and evaluated with measurement results from specialized meters. Thereby showing that the difference of the parameters is not significant between the monitor and the dedicated meter. The monitoring and control system meets the requirements of shrimp farming model in coastal areas of Vietnam. This is a solution that contributes to increasing productivity and quality of agricultural, aquatic products, livestock, eliminating manual intervention and minimizing production costs compared to manual monitoring and control methods which have caused a lot of damage to the fisheries sector.

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