



Autonomous Oxygenation System on Buoyancy for Aquaculture Ponds with Low Energy Consumption and Non-Mechanical Drives Unit

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Abstract

Aerating the pond by converting electrical energy into mechanical energy to mix air with water to produce dissolved oxygen (DO) is high electricity consumption, which is considered low efficiency compared to adding pure oxygen to the water of similar energy consumption. The idea proposed is to produce pure oxygen with solar energy to aerate the pond water efficiently. This can solve problems for farmers by reducing the mortality rate of aquatic animals and increasing productivity. An automatic oxygen-filling system on a buoy, therefore, is built in this research. Moreover, the performance of an automated oxygenation system on a buoyancy system for a low-energy aquaculture pond without mechanical propulsion for aerating was determined. This article discusses the construction of a floating buoy driven by solar energy and pure oxygen gas generating equipment. The system of automation control, processing and sensors, and data transmission with the server of the system is designed based on available technology. The result of research and local knowledge showed that the developed system can create a technique for producing oxygen gas sufficiently to supply water sources. It is a way to directly add 100% pure oxygen to water, which is more than the traditional method that adds only 21% pure oxygen. This system also focuses on low-cost development, at least lower than the market price, including in engineering, so that it is affordable by aqua farmers.

Keywords: oxygen generator; buoyance; aquaculture ponds; dissolved oxygen

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1. Introduction

Aquaculture has expanded widely due to market demand, and Thailand has high aquaculture potential. In 2015, freshwater animals produced in fisheries are up to 435,765 tons of aquatic animals with 25,469.5 million Baht [1]. It can be seen that the amount of aquatic animal production produced in 2015 was less than in 2009 at 553,700 tons, which is caused by problems such as the environment, water quality problems from natural disasters, and epidemic problems. The major problem is water quality problems [2]-[5]. There are many factors affecting water quality problems. Nevertheless, the primary causal factor is that the oxygen content in the water is less than the standard set for each aquaculture species due to the current increase in aquaculture densities per pond size [2], which causes the dissolved oxygen content to decrease rapidly. Another issue is the energy consumption of dissolved oxygen, which is particularly problematic in locations

where power is not yet available. Aquaculture growers have been obliged to use generators to generate power to aerate oxygen to the water. They employ a propeller-type aeration device, which is popular in aquaculture ponds but consumes much electricity to raise the dissolved oxygen in the pond because of the need to increase the number of impeller sets to enhance the oxygen content. Consequently, Figure 1 shows that farmers must pay more to produce aquatic animals.

Based on a study of the literature on aeration systems in aquaculture conducted by researchers. Solar energy has been discovered to be a viable energy source for aeration into the water in various ways [3]. Furthermore, the generation of hydrogen gas and oxygen from water is being investigated [4], [5], as the development of water quality management systems in ponds offers information or alerts farmers, and decreases losses or regulates water quality to maintain continuous quality [6]-[8].

However, in terms of water aeration efficiency or quality, the method of oxygenation using pure oxygen from liquid oxygen tanks was tested [9-10]. In

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Figure 1: The propeller aerators are commonly used in aquaculture ponds.

addition, automated oxygen monitoring and management systems for high-density marine fish farms are being developed. The device can accurately monitor the dissolved oxygen concentration of ponds and water treatment ponds, and it may show reports and graphics, as well as record data and alarms. The technology may also automatically boost the quantity of dissolved oxygen by instructing the oxygen machine and solenoid valve to provide pure oxygen at the specified time [9]. In only 5 minutes, the artificial oxygen mixer had the greatest oxygen diffusion rate of 4.93 kgO₂/hr. Under seawater standard circumstances, dissolved oxygen can be raised from 0.00 mg/l to saturation with a minimal wastage rate of 9.81 percent when utilized with pure oxygen gas. Consequently, in an emergency, oxygen mixers may be utilized in combination with pure oxygen. In terms of adding oxygen to improve water quality, it was discovered that the oxygen aeration pump had a maximum efficiency of 0.06 kgO₂/kw.hr owing to the lowest energy usage.

In the next section, the concept of the autonomous oxygenation system on buoyancy for aquaculture ponds with low energy consumption and non-mechanical drives unit is explained as the methodology and theory for building the prototype. Section 3 shows innovation buoyancy for aquaculture ponds prototype in the lab, and section 4 describes the experimental results when using the prototype on the farm. Finally, the conclusion is discussed in section 5.

2. Methodology and Theory

The amount of oxygen in aquaculture must always be controlled to maintain good quality which is a factor in the growth of aquatic animals. The low amount of oxygen in the water causes less oxygen to breathe in the water, and it also impairs the growth of the aquatic animal or weakens it, and eventually dies. This section will describe the modeling of buoyancy for aquaculture ponds. The concept consisted of the solar cell panel as an energy source, power control unit, and battery charge. The oxygenation equipment and oxygen measuring device were created. Also, the processing and control unit and the device for data communication system were built.

2.1. Buoyancy and stability

Buoyant Force (FB) is the loss weight of object on the liquid equalization to the liquid weight the same as the object floated volume. For the forces at work in buoyancy, the object floats at rest because the upward force of buoyancy is equal to the downward force of gravity [10]-[14]. The buoyant force is given in the equation (1).

$$\vec{F}_B = pVg \quad (1)$$

where \vec{F}_B is buoyant force measured in Newton (N), p is density of the liquid measured in g/cm^3 or kg/m^3 , V is the volume of the displaced body of liquid measured in m^3 , and g is the gravitational acceleration. Therefore, the buoyant force is equal to the weight of the liquid when the volume of the liquid is equal to the volume of the object floated under the liquid. Object density is the proportion between the mass and volume of the object. It can give as the equation (2) [15]-[18].

$$p = \frac{m}{V} \quad (2)$$

m is the mass of object measured in gram (g) or kilogram (kg). Then, we can design the buoyance for aquaculture ponds.

2.2. Energy and charger controller units

The electric producer is applied from the solar cell, which transduced the ultraviolet light to electrical energy. The electrical energy obtained is the direct current, measured in Watts (W). In the control units, there is the charge controller, an electric charge from the solar cell into the battery. However, the amount of electric charging is propitiated for saving the battery lifetime and supplying the electric current to the load. Therefore, when the battery is full, the charge controller stops or charges less. In other words, solar energy is controlled by the electric charge controller in case the battery is full. The energy is supplied to the system when there is no sunlight or at nighttime. The electrical supply from the solar system consists of the solar cell panel, battery, and solar charge controller.

1) The specification of solar cell panel can be calculated as the following. The processor and collector unit requires 5 Volts and 2 Amperes (10 Watts), the oxygen generator unit requires 12 Volts and 5 Amperes (60 Watts), and the control and oxygen supply units require 12 Volts and 1 Ampere (12 Watts). Consequently, the total power consumption is 82 Watts for 5 hours a day. Therefore, the solar cell panel is 82 Watts.

2) For the battery for collecting electric charge from the solar cell panel, Sealed Lead Acid (SLA) battery is used, which is cheaper than Deep Cycle (DC) battery. The battery requires 12 Volts and 70-ampere hours (Ah) or greater than, etc., 12 Volts 80 Ah and 12 Volts 100 Ah.

3) The electric charge controller controls the charge of electricity into the battery, thereby prolonging the battery's lifespan. The battery must be equal to or greater than the current (Amperes) flowing from the solar cell panel to the battery, so the specific charge controller should be larger than the current of the solar panel.

The technology of electrolysis oxygen generator is distinguished between water and gas by using the electrolysis method. It is the process of passing an external direct current (DC) current into the electrolyte solution through various metal plates. It conducts electricity through a solution and then causes a chemical reaction as shown in Fig. 2. The apparatus used to separate a solution with electricity is called an electrolyte cell or electrolytic cell. The main components of the system are the electrode, electrolyte solution container, and direct current generators such as batteries or solar cells, as shown in Fig. 2.

For oxygen concentrator design, 1) Electrode (anode and cathode) is stainless steel 316L, size 120x70 x 0.5 mm., total 8 pairs. 2) DC power supply uses electricity from the battery through the control system, size 12 Volts 80 Ah. 3) Electrolyte solution uses baking soda solution (NaHCO₃). The researchers applied electricity to the water to separate hydrogen and oxygen gas, which can be used to produce simple oxygen. The researchers developed a series of wet electrolysis, which is immersed in water and compounds to produce oxygen. Efficiency is improved by controlling the frequency voltage and continuing to supply electricity as shown in Fig.2.

2.3. *Developed a sensor to measure the dissolved oxygen content in water*

The dissolved oxygen sensor is divided into two groups. 1) Optical sensor is used to detect red light emitting from blue light emitting coated with an oxygen-enriched substance. 2) Electrochemical sensor uses the principle of detecting ions in a solution from electrochemical electrolysis. The researchers applied micro-current sensor technology to a polarographic DO sensor through a coupling and amplifica-

tion circuit to measure the measurement process and the specified probe properties. This is in the process of further development, calibration, and performance of use for the future.

3. Innovation Buoyancy for Aquaculture Ponds

All developed systems were installed on buoys for preliminary testing. As shown in Fig. 3, the systems include the solar generation system, the oxygen generation system, and the sensor and control system.

The energy from the solar cells was tested through the charge controller from 8:00 a.m. to 5:00 p.m. Then the light intensity, charge voltage, charge current and electric power from the solar panel were collected. The test was repeated five times, and the results were analyzed by statistical data, as shown in Table 1. From Table 1, the system can charge energy from sunlight for about 8 hours, focusing on the use of open space (floating on the surface of the pond), which is sufficient to charge the battery for use after sunset or not enough light.

The use of an automated oxygenation system on the developed buoys was tested. Production of pure oxygen (O₂) was added to the aquaculture tank. Four-three-month-old Red Tilapia were taken to test and reared. Then, the concentration of pure oxygen (O₂) produced by the developed system was approximately 94.4 percent, measured with the Oxygen Analyzer model JAY-120. Table 2 shows that the designed oxygen generation system can produce oxygen for aquatic animals when used in the pond as well. The value of DO is within the standard that aquatic animals can survive when compared to a small pond that uses water circulation and a small jet system. It was found that in the experiment, the system can produce oxygen continuously for about 8-9 hours continuously. It is electrically charged during the day and at night using the power of a battery charged by a solar panel.

4. Experimental and Results

The eight low-power, non-mechanical-powered, buoyancy-based automated oxygenation systems for aquaculture ponds were built. The actual test was carried out in the animal pond at Nong Din Daeng Sub-district, Mueang District, Nakhon Pathom Province, Thailand. The details of the construction of an automatic oxygen filling system on the developed buoys are presented below.

4.1. *Implementation of the autonomous oxygenation system on buoyancy for aquaculture ponds*

The 8 buoy systems are set up at the point that needs to add oxygen within the culture pond. Next, the water quality standards such as pH, salinity, and dissolved oxygen in water were measured before the introduction of the developed oxygen filling system. When the

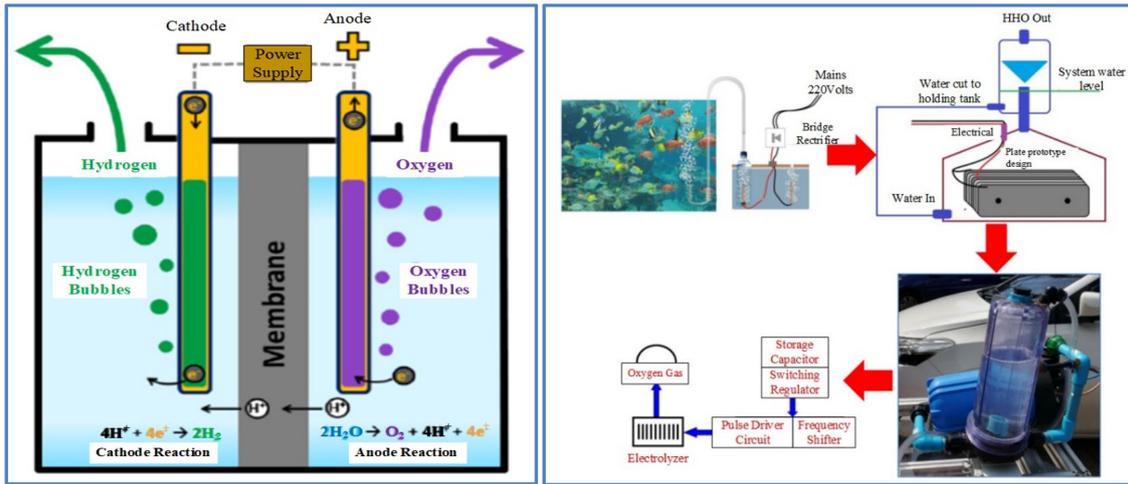


Figure 2: Principle of separation of gas from water by electrolysis method [11].

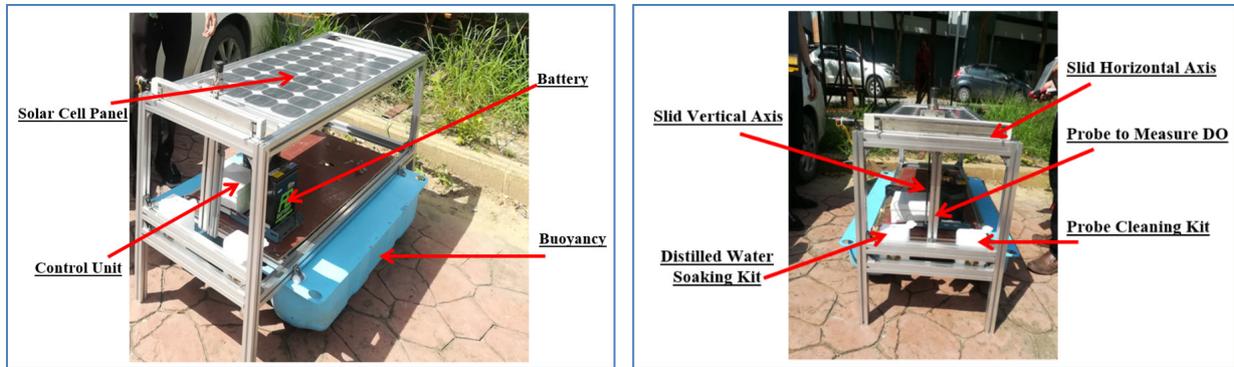


Figure 3: Solar power generation and oxygen generation system on a prototype buoy.

Table 1. Solar cell battery charge test results.

Time Period	Number of Test (Time)	Mean of Test Charging the Power from Solar Cell			
		Light intensity (lux)	Voltage charging (Volt)	Current charging (Ampere)	The Power from Solar Cell Panel (Watt)
8.00 am.	5	16220	12.5	0.6	7.50
9.00am.	5	23870	12.7	0.7	8.89
10.00am.	5	43650	12.8	0.9	11.52
11.00am.	5	76490	13.0	1.02	13.26
12.00am.	5	98035	13.7	1.05	14.39
13.00pm.	5	93750	13.5	1.07	14.15
14.00pm.	5	86180	13.1	0.95	12.45
15.00pm.	5	5690	13.1	0.75	9.83
16.00pm.	5	3990	12.7	0.72	9.14
17.00pm.	5	1130	12.4	0.61	7.56

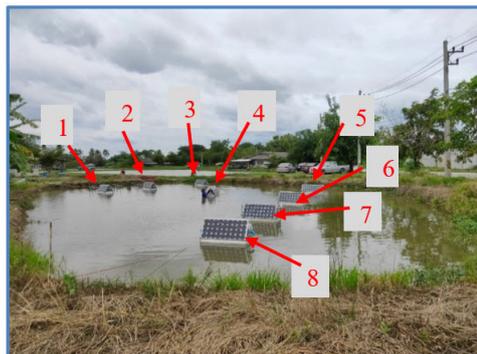
system was activated, the dissolved oxygen measurement test was performed every 1 hour, starting from 8:00 AM to 7:00 PM. The tests were repeated five times and the measured values were averaged.

From Table 3, the study found that the system can supply oxygen to the 168 cubic meter pond. By estimating that one set of buoys can produce approximately of 394.45 oxygen (mg-O₂/kg/h). It can produce oxygen for 400 fish at 500g size. The value of oxygen in water (DO) was approximately not less than 5 mg/l throughout the experiment. The system

can measure water quality and transmit data to the server system at any time. The oxygen supply can be controlled manually (Manual) or automatically via wireless communication/via Web application, including charging and supplying power. It can supply oxygen to the water at about 390 mgO₂/kg/h. Additionally, the system is able to alert the maintenance via an audit file through the visual display device and test the functionality via the Internet or web application.

Table 2. Comparison of two aerations dissolved oxygen before-after.

Time Measurement (minute)	Number of Test (time)	Mean of Air Temperature (Celsius)	Mean of Water Temperature (Celsius)	Amount of Dissolved Oxygen (DO) (mg/l)			
				Electrolysis oxygen generator method		PSA Concentration oxygen generator method	
				Before	After	Before	After
10	5	34.3	32.2	5.40	6.40	5.56	6.28
20	5	34.3	32.2	5.40	6.45	5.56	6.35
30	5	34.2	32.3	5.40	6.59	5.56	6.39
40	5	34.1	31.2	5.40	6.83	5.56	6.54
50	5	34.1	31.3	5.40	6.94	5.56	6.68
60	5	34.0	31.2	5.40	7.06	5.56	6.87
70	5	33.2	30.5	5.40	7.18	5.56	7.03
80	5	33.2	30.3	5.40	7.30	5.56	7.09
90	5	33.3	30.1	5.40	7.43	5.56	7.11
100	5	33.2	30.0	5.40	7.46	5.56	7.20
110	5	32.3	30.3	5.40	7.55	5.56	7.26
120	5	32.2	30.2	5.40	7.59	5.56	7.30

**Figure 4:** The implementation of autonomous oxygen generation on buoyancy for aquaculture ponds**Table 3.** The results of testing the implementation of the automated oxygen filling system on the developed buoys.

Buoyancy Item	Mean of Air Temperature (Celsius)	Mean of Water Temperature (Celsius)	Amount of Dissolved Oxygen (DO) (mg/l)	
			Before	After
1	33.89	32.56	4.21	5.09
2	33.76	32.44	4.21	5.13
3	33.89	32.56	4.35	5.13
4	33.89	32.56	4.21	5.13
5	33.89	32.56	4.54	5.15
6	33.89	32.56	4.34	5.07
7	33.89	32.56	4.41	5.12
8	33.76	32.44	4.49	5.14

4.2. Cost and saving for farmers

Analysis and evaluation of engineering economics from the buoyancy oxygen filling system consisted of 1) electric power generation and distribution system 120 watts (12 V, 50 Ah), costing 10,000 baht, 2)

oxygen production system not less than 1.25 LPM, electric power, costing 10,000 baht, 3) Water Oxygen Monitoring (DO) system, costing about 10,000 baht, 4) control system and data transmission, costing about 5,000 baht, and 5) floating frame and other ac-

cessories, costing about 5,000 baht. Finally, the price of the developed system is about 40,000 baht per set. It can continuously produce at least 90% pure oxygen gas at least 180 liters per hour or at least 900 liters per day, from 5 working hours. The designed and developed buoyancy oxygenation system can produce approximately 180,000 liters of oxygen per year (based on 200 working days per year). Oxygen transfer efficiency (SOTR) is not lower than 0.020 kg oxygen per hour, which can estimate the cost of operating the break-even point payback period and net present value (NPV) as follows: 1) estimated operating expenses is equal to 106,800.00 baht per year, 2) break-even point is to produce 1,702.00 kg per year, and 3) payback period is 0.925 years or approximately 11 months. Finally, the net present value (NPV) is 43,200.00 baht.

5. Conclusion

This research and development is a design of buoyancy with its power source. It is an oxygen production device, the control system, processing, and sensors with solar energy. Pure oxygen gas is generated and information is sent and received by working with the server of the designed system. This research focuses on techniques for producing sufficient oxygen for supplying to water sources according to the scope of technology and energy available. It is controlled by a microcontroller or computer system automatically. The design is low-cost research and development which all components used are domestic materials with the price lower than the market price or based on appropriate technology, which uses various knowledge to design an engineering system for agriculture to be practical in the field.

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