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Solar-Powered Bubble Aerator with Water Quality GSM Based Monitoring System for Fish Cages

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ABSTRACT

This project study aimed to rehabilitate, modify and install a Solar-Powered Bubble Aerator to improve the aeration capability of the existing Bubble Aerator to prevent fish kill. The device does not require connection to the electrical power grid and may be used in any location. The Solar-Powered Bubble Aerator has been developed to control dissolved oxygen (DO) levels suitable for fish farming. The water conditions in a fish farm was measured real-time by a water quality monitoring device in the fish cage. The project consists of solar panels which were used as an energy source connected to the solar charge controller then to the battery to store the energy. The temperature sensor and dissolved oxygen sensor measures the temperature and amount of dissolved oxygen in the water respectively and Arduino Mega acts as the brain of the system. The GSM Module was responsible in sending a text message to the owner of the fish cage about the status of the project and the measured temperature and oxygen. The inverter converts the DC voltage from the battery to AC voltage to power the air compressor and the solenoid valve was used to diffuse air from the air compressor. To DO levels shows a decreased in value during the night and when the temperature is high which decreases the capability of water to hold oxygen. By using the bubble aerator DO levels in the fish cage can be improved to a level suitable for fish farming.

Key words:aeration, compressor, dissolved oxygen, solar power, temperature

INTRODUCTION

In the modern period, electricity became abundant as it develops in the society. Electricity began to improve and it is the greatest blessing of the wide technology innovations in the planet earth. It became one of the basic needs of people in the modern life and without it, people cannot survive. Electricity is important to homes and industries as many use it in their daily life. It is one of the vital parts that functions the society because more of the devices at homes, offices and other business are running because of electricity. Today, electricity is essentials to life and without it, people's lives will come to a standstill.

One of the important sources of renewable energy and technologies is the solar energy, passive or active depending on how it will be

captured and distributed and will be converted into solar power. Solar energy is the energy coming from the heat and light of the sun. This is very helpful for generating electricity, for lighting and providing comfortable environment even in domestic, commercial and industrial places. Solar energy is also used in many applications because it is very useful in many things. Over many places in the Philippines, many complicated things can be powered by a solar energy, not just by providing lights, but also converting the sun's heat and light to energy that can make other living things alive.[29]

Seas, ponds, lake, river and falls are classifications of aquatic resources, which have multiple roles in the human environment. It is a natural resource not only supporting the human's need but also providing shelter to plants and animals. Aquatic resources also encompass the linkages between freshwater systems and the downstream coastal areas into which it drains, where it sustains biologically rich and commercially important coastal ecosystem. Philippines have many aquatic resources that help the economy rise. In over places around, aquatic resources is being conserved and manage to improve by government agency – Bureau of Fisheries and Aquatic Resources to ensure the sustainable development of aquatic resources in places.[3]

In Taal, Batangas, there is a lake known for being an ecosystem that supports a diverse aquatic fauna comprising of both freshwater and marine species. This lake surrounds the small and beautiful volcano, which is the home of a variety of fish. Fishing is the most important industry in that area for having fresh fish for sale open at air market and readily prepared for local restaurants. Fishing is allowed as long as a person catches fish through the safest ways. However, upon research, fish kills are highly demanding which causes environmental stress.[4] According to Bureau of Fisheries and Aquatic Resources (BFAR), notable fish kill events happened last January 5, 2008, where 50 metric tons of tilapia died, on May 29, 2011, where 750 metric tons of tilapia and milkfish died, and the latest fish kill event happened last June 11, 2018 where 215 metric tons of milkfish died at the Agoncillo, Batangas area only. The causes of these problems are found to be the lack of oxygen in the lake. Many factors reduce the ability of the water to hold oxygen. One of it is the temperature of the water surface that lessens dissolved oxygen as water temperatures rises. There are also many reports of fish kills, not only in Taal Lake, but in many places of the Philippines. The phenomena of changing temperature is the cause especially in warm months and during rainy months when typhoon occur. The volume of the fish in the cage can also cause fish kills because the amount of dissolved oxygen available cannot sustain the amount of fishes in the fish cages.

Based on the problems, water pumps and aerators are used in helping to improve the quality of water surface. Aeration can break down unwanted bacteria, help prevent mosquito infestation and remove foul odors from a bodies of water—all by circulating the water and adding dissolved oxygen. A solar powered aerator that uses a compressor helps pump air through tubing that diffuses oxygen into the water body. The air circulates in the water to provide increases of oxygen and equalizing the water temperature. This aeration work through sun's rays that converted into power source. The previous Solar-Powered Bubble Aerator only aerates a fish cage during the time before dawn when the amount of oxygen in the water is low.

To improve the aeration capability, the proponents modified the existing Solar-Powered Bubble Aerator so that the bubble aerator only provides sufficient oxygen in a single fish cage when only it was needed. By installing a temperature sensor and dissolved oxygen sensor to the existing Bubble Aerator, so that the aerator only operated when the dissolved oxygen

in the water was lower than normal and when the temperature of the water was abnormally high.

OBJECTIVES OF THE STUDY

The project primarily aim to rehabilitate, modify and install a Solar-Powered Bubble Aerator.

Specifically, the study aims to attain the following objectives:

1. To evaluate the existing Solar-Powered Bubble Aerator in terms of:
    1. Design
    2. Construction
    3. Operation
    4. Areas for Improvement
2. To determine the project's design considerations and requirements from the following standards:
    1. Philippine Electrical Code (PEC)
    2. International Electrotechnical Commission (IEC)
    3. Institute of Electrical and Electronics Engineers (IEEE)
    4. National Electrical Manufacturers Association (NEMA)
    5. Bureau of Fisheries and Aquatic Resources (BFAR)
    6. Department of Environment and Natural Resources (DENR)
3. To prepare project design plan and specifications:
    1. General Description of the Project
    2. Design Computation and Analysis
    3. Schematic Diagrams
    4. Program and its Implementation
    5. Bill of Materials and Specification
4. To present the overall financial picture in terms of:
    1. Project Cost
    2. Payback Period
5. To determine the method of Fabrication, Assembly and Installation:
    1. Methods
    2. Machine/Tools
6. To test the performance of the Modified Solar Powered Bubble Aerator as to its functionality and capability:
    1. Procedures
    2. Results and Discussion
7. To determine the socio-economic benefit of the study.

RESEARCH METHODOLOGY

Methods of Fabrication and Assembly

The following steps was executed in the fabrication and assembly of the prototype:

1. Replacement of Components. By running the Bubble Aerator one more time, it was discovered that some of the components were not functional and needed replacement. The functional components were the solar panels and the solar charge controller. The inverter was not functional and need replacement. While the previous battery and compressor was already gone thus it were replaced completely.

2. Preparation of Auxiliary Cabinet. The auxiliary cabinet was cleaned because it was staying in the warehouse for years. But since the cabinet paint was in good condition, the cleaning was enough for the cabinet. A heat rejection insulation foam was also installed inside the cabinet to lessen the heat inside the cabinet and protects the components from overheating.

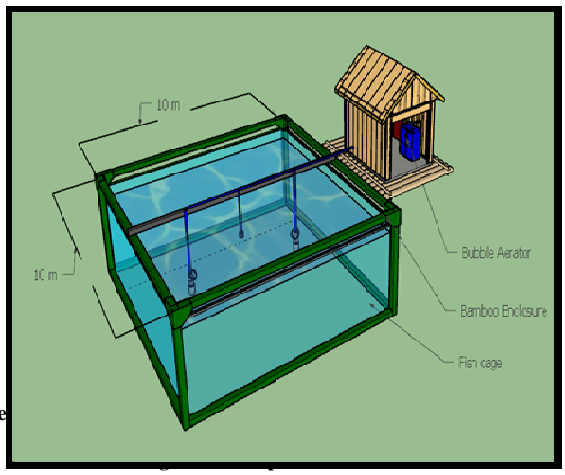
3. Installation of the Auxiliary Components. The new battery was installed to the different room of the cabinet to prevent sulfuric acid emitted not to cause damage on other components. The air compressor was placed in the lower room alone for better ventilation. The solenoid valve was installed to the compressor to control the output of the air. And the Arduino Mega controls the solenoid to open or close.

4. Preparation and Installation of Hose and Sensors. Holes were punctured to the side of the cabinet as the exit point of the sensors and the hose to the fish cage. A diffuser was attached to the end of the hose for better aeration. A metal

bar was mounted on the fish cage to attach the sand bags to be used as a counter weight to keep the hoses underwater when air comes out. The sensors were connected to the Arduino Mega and submerged 5m below the water surface to measure the temperature and dissolved oxygen of the water.

DESIGN AND LAYOUTS

Construction layout is composed of different views that display the whole structure with its component and dimensions. The different views include the perspective, front, and bottom view.



Figure

Figure 1 shows the perspective view of the Modified Solar-Powered Bubble Aerator. This figure shows the fish cage, the placement of the hose and the sensor and the position of the cabinet that houses the components.

Figure 2.Exploded View

Figure 2 shows the exploded view of the Modified Solar-Powered Bubble Aerator the battery was installed in the different cabinet from the electrical and electronics components and the compressor was installed at the bottom cabinet for better ventilation.

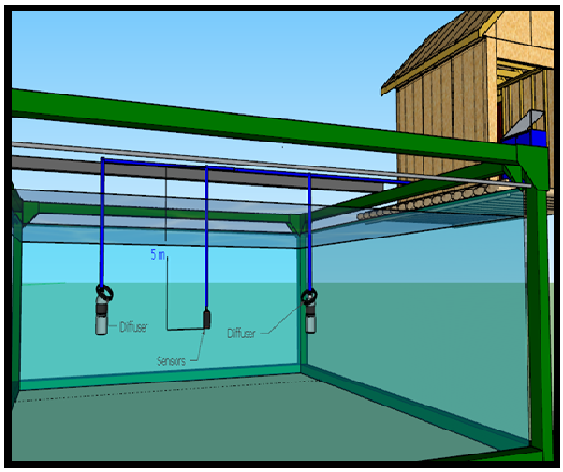
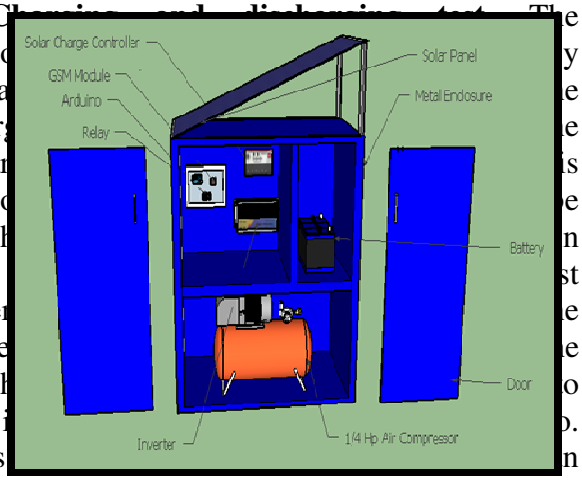


Figure 3. Bottom View

Figure 3 shows the bottom view of the fish cage. It also illustrates the different components under the water. The temperature sensor and the dissolved oxygen sensor was installed between the plastic hoses. A counter weight was installed to keep the plastic hose in place during diffusion. Both the sensors and diffusers were submerged 5 meters below the lake surface.

Method of Testing

Charging and discharging test. The proto y stora e char e sola s disc e disch n the st deter e batte e disch o the o. This n



supply the given load with in a specific length of time.

Charging Test. The data inTable 1 shows the results on the charging test. The results of the test performed in 30 days for one, three, and six hours of charging show the initial and final voltage and the battery status.

Table 1: Charging of Battery Test

Charging Time (hr)	Trial	(Charging) Battery Condition		Battery Status
		Initial Voltage (V)	Final Voltage (V)	
1	1	10.51	10.92	87%
	2	10.56	10.97	88%
	3	10.52	10.91	88%
	4	10.51	10.91	87%
	5	10.53	10.93	88%
	6	10.54	10.94	89%
	7	10.51	10.91	88%
	8	10.54	10.94	88%
	9	10.53	10.93	88%
	10	10.51	10.91	88%
	11	10.5	10.9	87%
	12	10.54	10.94	88%
	13	10.56	10.96	89%
	14	10.56	10.96	88%
	15	10.5	10.9	88%
	16	10.54	10.94	88%
	17	10.53	10.93	89%
	18	10.52	10.92	87%
	19	10.51	10.91	88%
	20	10.54	10.94	87%
	21	10.55	10.95	88%
	22	10.5	10.9	87%
	23	10.54	10.94	89%
	24	10.51	10.91	88%
	25	10.53	10.93	87%
	26	10.52	10.92	89%
	27	10.54	10.94	88%
	28	10.51	10.91	87%
	29	10.52	10.92	88%
	30	10.56	10.96	88%
3	1	10.92	11.67	93%
	2	10.96	11.71	94%
	3	10.91	11.66	94%
	4	10.91	11.66	93%
	5	10.93	11.68	94%
	6	10.94	11.69	95%
	7	10.91	11.66	94%
	8	10.94	11.69	94%
	9	10.93	11.68	94%
	10	10.91	11.66	94%
	11	10.9	11.65	93%
	12	10.94	11.69	94%
	13	10.96	11.79	96%
	14	10.96	11.71	94%
	15	10.9	11.65	94%
	16	10.94	11.69	94%
	17	10.93	11.68	95%
	18	10.92	11.67	93%
	19	10.91	11.66	94%
	20	10.94	11.69	93%
	21	10.95	11.7	94%
	22	10.9	11.65	93%
	23	10.94	11.69	95%
	24	10.91	11.66	94%
	25	10.93	11.68	93%
	26	10.92	11.67	95%
	27	10.94	11.69	94%
	28	10.91	11.66	93%
	29	10.92	11.67	94%
	30	10.96	11.71	94%
6	1	11.67	12.4	100%
	2	11.71	12.4	100%
	3	11.66	12.4	100%
	4	11.66	12.4	100%
	5	11.68	12.4	100%
	6	11.69	12.4	100%
	7	11.66	12.4	100%
	8	11.69	12.4	100%
	9	11.68	12.4	100%
	10	11.66	12.4	100%
	11	11.65	12.4	100%
	12	11.69	12.4	100%
	13	11.71	12.4	100%
	14	11.71	12.4	100%
	15	11.65	12.4	100%
	16	11.69	12.4	100%
	17	11.68	12.4	100%
	18	11.67	12.4	100%
	19	11.66	12.4	100%
	20	11.69	12.4	100%
	21	11.7	12.4	100%
	22	11.65	12.4	100%
	23	11.69	12.4	100%

Charging Time (hr)	Trial	(Charging) Battery Condition		Battery Status
		Initial Voltage (V)	Final Voltage (V)	
	24	11.66	12.4	100%
	25	11.68	12.4	100%
	26	11.67	12.4	100%
	27	11.69	12.4	100%
	28	11.66	12.4	100%
	29	11.67	12.4	100%
	30	11.71	12.4	100%

Table 1 shows that the more charging time, the higher the voltage of the battery. The highest recorded voltage for the one hour of charging was 10.97 V, which is the second trial and puts the battery to 88%. For the three hours of charging, the thirteen trial has the highest voltage, which is 11.79 V, which puts the battery at 96%. In addition, for the six hours charging time, the battery reached it 100% capacity. The test shows that the full charge voltage of the battery is 12.4 V

Discharging Test. The data inTable 2 shows the results on the discharging test. The results of the test performed in 30 days for one, three, and six hours of charging show the initial and final voltage and the battery status.

Table 2: Discharging of Battery Test

Discharging Time	Trial	(Discharging) Battery Condition		Battery Status
		Initial Voltage (V)	Final Voltage (V)	
30mins	1	12.15	11.66	94%
	2	11.66	11.15	90%
	3	11	10.5	85%
	4	12.4	11.9	96%
	5	11.9	11.4	92%
	6	11.4	10.9	88%
	7	12.37	11.87	96%
	8	11.87	11.37	92%
	9	12.4	11.9	96%
	10	12.4	11.9	96%
	11	11.89	11.39	92%
	12	11.37	10.87	88%
	13	11.86	11.36	92%
	14	11.39	10.89	88%
	15	11	10.5	85%
	16	11.87	11.37	92%
	17	11.36	10.86	88%
	18	12.4	11.9	96%
	19	11.96	11.46	92%
	20	12.4	11.9	96%
	21	11.98	11.48	93%
	22	11.96	11.46	92%
	23	12.4	11.9	96%
	24	11.91	11.41	92%
	25	11.38	10.88	88%
	26	12.4	11.9	96%
	27	11.92	11.42	92%
	28	11.44	10.94	88%
	29	12.4	11.9	96%
	30	11.96	11.46	92%
1 hr.	1	12.15	11.45	88%
	2	11.25	10.5	92%
	3	11.58	10.85	92%
	4	12.4	11.4	92%
	5	11.9	10.9	88%
	6	11.87	10.87	88%
	7	12.37	11.37	88%
	8	12.4	11.4	84%
	9	12.38	11.38	92%
	10	11.89	10.89	88%
	11	11.86	10.86	92%
	12	11.87	10.87	89%
	13	11.36	10.36	88%
	14	12.4	11.4	92%
	15	11.96	10.96	88%
	16	12.36	11.36	84%
	17	11.98	10.98	92%
	18	11.96	10.96	88%
	19	12.35	11.35	84%
	20	11.91	10.91	88%
	21	11.38	10.38	91%
	22	12.4	11.4	92%
	23	11.92	10.92	91%
	24	11.44	10.44	92%
	25	11.96	10.96	91%
	26	12.24	11.24	88%
	27	12.37	11.37	92%
	28	12.24	11.24	92%
	29	12.4	11.4	92%

Discharging Time	Trial	(Discharging) Battery Condition		Battery Status
		Initial Voltage (V)	Final Voltage (V)	
	30	12.34	11.34	88%
2 hrs.	1	12.4	10.5	85%
	2	12.4	10.54	85%
	3	12.4	10.52	85%
	4	12.4	10.53	85%
	5	12.4	10.5	85%
	6	12.4	10.58	85%
	7	12.4	10.54	85%
	8	12.4	10.54	85%
	9	12.4	10.52	85%
	10	12.4	10.51	85%
	11	12.4	10.54	85%
	12	12.4	10.5	85%
	13	12.4	10.5	85%
	14	12.4	10.5	85%
	15	12.4	10.53	85%
	16	12.4	10.54	85%
	17	12.4	10.5	85%
	18	12.4	10.53	85%
	19	12.4	10.54	85%
	20	12.4	10.56	85%
	21	12.4	10.54	85%
	22	12.4	10.54	85%
	23	12.4	10.52	85%
	24	12.4	10.51	85%
	25	12.4	10.5	85%
	26	12.4	10.53	85%
	27	12.4	10.54	85%
	28	12.4	10.5	85%
	29	12.4	10.52	85%
	30	12.4	10.51	85%

Table 2 shows that the lowest voltage allowable for the battery is 10.5 V. And the table shows that the battery percentage lower by 6% for every 30 minutes of discharging. In addition, the lowest possible battery percentage is 85%. This was the lowest battery percentage where the lead-acid battery will stay healthy and can reach 100% for the next charging and much lower than this percentage will harm the battery.

Aeration Test. The values of dissolved oxygen and temperature was measured in a given day at a specific time. And then, the next day, the bubble aerator was used for one hour and then the dissolved oxygen and temperature was measured again. This test was conducted with different pressure of the air output.

Aeration Test. The data inTable 3 shows the results on the aeration test. The results of the test performed in six days for 40, 70, and 100 psi of pressure, showing the depth of the lake where the initial and final values of temperature and dissolved oxygen was measured.

Table 3: Aeration Test

Pressure psi	Depth (m)	Values		Values	
		T_i (^oC)	DO_i (mg/L)	T_f (oC)	DO_f (mg/L)
40	**0 m**	33	8.0	33.5	8.0
	1 m	33	7.85	33	7.91
	2 m	33	7.56	33	7.65
	3 m	32.5	6.52	32.5	6.67
	4 m	32.5	6.16	32.5	6.29
	5 m	32.5	6.04	32	6.16
	6 m	32	6.37	32	6.51
	7 m	32	6.50	32	6.60
	8 m	31.5	6.47	31.5	6.56
	9 m	31	6.45	31	6.52
	10 m	30	6.40	31.5	6.48
70	**0 m**	33.5	8.0	33.5	8.0
	1 m	33	7.83	33	7.95
	2 m	33	7.51	33	7.71
	3 m	32.5	6.43	33	6.73
	4 m	32.5	6.19	32.5	6.34
	5 m	32	6.11	32.5	6.20
	6 m	32	6.42	32.5	6.59
	7 m	32	6.53	32	6.74

Pressure psi	Depth (m)	Values T_i (^oC)	Values DO_i (mg/L)	Values T_f (oC)	Values DO_f (mg/L)
	8 m	31.5	6.56	31	6.72
	9 m	31.5	6.58	31	6.69
	10 m	30	6.62	30.5	6.66
	0 m	33.5	8.0	33	8.0
	1 m	33	7.79	33	7.98
	2 m	33	7.46	32.5	7.89
100	**3 m**	32.5	6.51	32.5	6.77
	4 m	32.5	6.24	32	6.46
	5 m	32	6.07	32	6.32
	6 m	32	6.19	32	6.73
	7 m	32	6.74	32	6.84
	8 m	31.5	6.69	31	6.81
	9 m	31	6.64	31.5	6.76
	10 m	30	6.67	30	6.72

Table 3 shows the initial and final values of the temperature and dissolved oxygen.On the first day, the temperature and dissolved oxygen was measured during 11:00 AM. Then the next day, the bubble aerator was turned on with a 40-psi output of air from 10:00 AM to 11: AM. Then the values was measured again and compared to the initial values. These was a slight increase in the dissolved oxygen in the water with the same value of the temperature. The lowest DO value measured was 6.04 mg/L.

In the third day, the temperature and dissolved oxygen was measured during 11:00 AM. Then the next day, the bubble aerator was turned on with a 70-psi output of air from 10:00 AM to 11: AM. Then, the values was measured again and compared to the initial values. The increase in the dissolved oxygen in the water with the same value of the temperature was more than the 40-psi pressure applied. The lowest DO value measured was 6.11 mg/L.

In the fifth day, the temperature and dissolved oxygen was measured during 11:00 AM. Then the next day, the bubble aerator was turned on with a 100-psi output of air from 10:00 AM to 11: AM. Then, the values was measured again and compared to the initial values. The value of the dissolved oxygen in the water with the same value of the temperature shows the highest increase in value compared to other pressures applied. The lowest DO value measured was 6.07 mg/L.

To show the data more presentably a graph was present below:

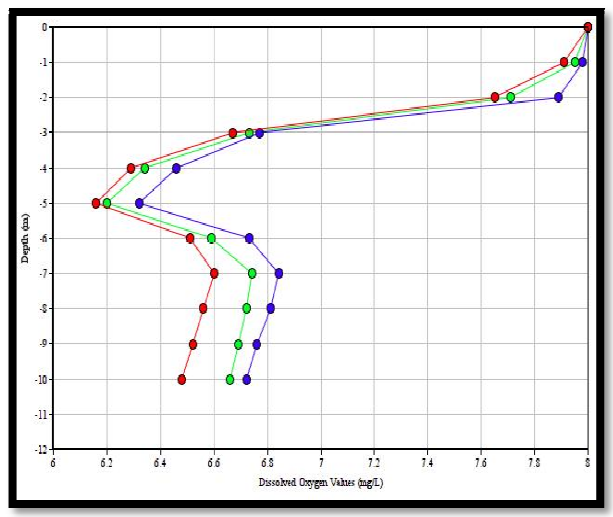


Figure 4. Comparison of DO Values with Different Applied Pressures

Figure 4 shows the difference on the aeration capability of the project when the pressure on the air were to increase. The 100-psi pressure has the most favorable results.

Functionality test. In the functionality test, the program of the Arduino Mega was tested. The Temperature and Dissolved Oxygen Sensor was placed five meters below the lake surface and if the temperature detected was high or the dissolved oxygen is low, the GSM Module should send a text message to the fish cage owner about the temperature or dissolved

oxygen measured and the solenoid valve should open to output the air from the compressor.

Functionality Test. The data inTable 4 shows the results on the functionality test. The results of the test performed in seven days shows the time the aeration started and finished, the message delay from the GSM Module, the values of the temperature and dissolved oxygen and the activation status of the project.

Table 4:Functionality of the Equipment Test

Trial	Time	Message Delay	Temp (C)	Oxygen (mg/L)	Activation
1	**Time Start** 2:56 PM	Message not Received	-	-	ON
	3:11 PM	-	Measuring	Measuring	OFF
	3:11 PM	-	Low	Low	ON
	3:26 PM	-	Measuring	Measuring	OFF
	3:26 PM	-	Low	Low	ON
	3:41 PM	-	Measuring	Measuring	OFF
	Time Finished 3:41 PM	Message not Received	Normal	Normal	OFF
2	**Time Start** 5:07 AM	2 secs.	Normal	3.99	ON
	5:22 AM	-	Measuring	Measuring	OFF
	5:22 AM	-	Normal	Low	ON
	5:37 AM	-	Measuring	Measuring	OFF
	5:37 AM	-	Normal	Low	ON
	5:52 AM	-	Measuring	Measuring	OFF
	Time Finished 5:52 AM	2 secs.	Normal	4.02	OFF
3	**Time Start** 2:40 PM	2 secs.	35.00	Normal	ON
	2:55 PM	-	Measuring	Measuring	OFF
	2:55 PM	-	High	Normal	ON
	3:10 PM	-	Measuring	Measuring	OFF
	3:10 PM	-	High	Normal	ON
	3:25 PM	-	Measuring	Measuring	OFF
	3:25 PM	-	High	Normal	ON
	3:40 PM	-	Measuring	Measuring	OFF
	Time Finished 3:40 PM	2 secs.	34.5	Normal	OFF
4	**Time Start** 5:00 AM	2 secs.	Normal	3.99	ON
	5:15 AM	-	Measuring	Measuring	OFF
	5:15 AM	-	Normal	Low	ON
	5:30 AM	-	Measuring	Measuring	OFF
	5:30 AM	-	Normal	Low	ON
	5:45 AM	-	Measuring	Measuring	OFF
	Time Finished 5:45 AM	2 secs.	Normal	4.02	OFF
5	**Time Start** 3:12 PM	2 secs.	35.00	Normal	ON

Trial	Time	Message Delay	Temp (C)	Oxygen (mg/L)	Activation
	3:27 PM	-	Measuring	Measuring	OFF
	3:27 PM	-	High	Normal	ON
	3:42 PM	-	Measuring	Measuring	OFF
	Time Finished 3:42 PM	2 secs.	34	Normal	OFF
6	**Time Start** 5:17AM	2 secs.	Normal	2.74	ON
	5:32 AM	-	Measuring	Measuring	OFF
	5:32 AM	-	Normal	Low	ON
	5:47 AM	-	Measuring	Measuring	OFF
	Time Finished 5:47 AM	2 secs.	Normal	4.12	OFF
7	**Time Start** 1:04 PM	2 secs.	35.5	Normal	ON
	1:19 PM	-	Measuring	Measuring	OFF
	1:19 PM	-	High	Normal	ON
	1:34 PM	-	Measuring	Measuring	OFF
	Time Finished 1:34 PM	2 secs.	34.5	Normal	OFF
8	**Time Start** 3:34 PM	2 secs.	Normal	3.36	ON
	3:49 PM	-	Measuring	Measuring	OFF
	3:49 PM	-	Normal	Low	ON
	4:04 PM	-	Measuring	Measuring	OFF
	Time Finished 4:04 PM	2 secs.	Normal	4.04	OFF
9	**Time Start** 5:45AM	2 secs.	Normal	3.89	ON
	6:00 AM	-	Measuring	Measuring	OFF
	Time Finished 6:00 AM	2 secs.	Normal	4.01	OFF
10	**Time Start** 12:14 PM	2 secs.	Normal	3.76	ON
	12:29 PM	-	Measuring	Measuring	OFF
	12:29 PM	-	Normal	Low	ON
	12:44 PM	-	Measuring	Measuring	OFF
	Time Finished 12:44 PM	2 secs.	Normal	4.03	OFF

Table 4 shows the functionality test of the Modified Solar-Powered Bubble Aerator. In the first trial, the Bubble Aerator started at 2:56 PM and ended at 3:43 PM. There is no message received from the GSM Module while using a GLOBE sim card. Thus, the value of the temperature and dissolved oxygen was not determined.

On the second trial, the proponents changed the sim card to a TNT sim card. The text message received at 5:07 AM saying that the value of the DO is 3.99, which is low, and then the compressor was activated. The Bubble Aerator stopped at 5:55 AM when the DO is at its normal value.

This result was the same in the study of Endo, et al., (2006) on using a microscopic bubble generating system to control dissolved oxygen levels suitable for fish farming where the dissolved oxygen was low during the time before dawn and it start to increase again after dawn. Because during the night, the plants consume oxygen to live because of the absence of the sun and photosynthesis cannot be done. However, after sunrise the DO level starts to increase, the same as the result of the second trial.

On the third trial, the Bubble Aerator started at 2:40 PM. The text message said that the value of the temperature of the water is 35, which is high, and then the compressor was activated. The Bubble Aerator stopped at 3:32 PM when the temperature is at its normal value. This result proves that the hottest time of the day is around 3 in the afternoon.

On the fourth trial, the Bubble Aerator started at 5:00 AM. The text message said that the value of the DO is 3.99, which is low, and then the compressor was activated. The Bubble Aerator stopped at 5:45 AM when the DO is at its normal value.

On the fifth trial, the Bubble Aerator started at 3:12 PM. The text message said that the value of the temperature of the water is 35, which is high, and then the compressor was activated. The Bubble Aerator stopped at 3:42 PM when the temperature is at its normal value.

On the sixth trial, the Bubble Aerator started at 5:17 AM. The text message received was saying that value of the DO is 2.74, which is low, and then the compressor was activated. The Bubble Aerator stop at 5:47 PM when the DO is at its normal value.

On the seventh trial, the Bubble Aerator started at 1:04 PM. The text message said that the value of the temperature of the water is 35.5, which is high, and then the compressor was activated. The Bubble Aerator stopped at 1:34 PM when the temperature is at its normal value.

On the eight trial, the Bubble Aerator started at 3:34 PM. The text said that the value of the DO is 3.36, which is low, and then the compressor was activated. The Bubble Aerator stopped at 4:04 PM when the DO is at its normal value.

On the ninth trial, the Bubble Aerator started at 5:45 AM. The text message said that the value of the DO is 3.89, which is low, and then the compressor was activated. The Bubble Aerator stopped at 6:00 AM when the DO is at its normal value.

On the tenth trial, the Bubble Aerator started at 12:14 PM. The text said that the value of the DO is 3.76, which is low, and then the compressor was activated. The Bubble Aerator stopped at 12:44 PM when the DO is at its normal value.

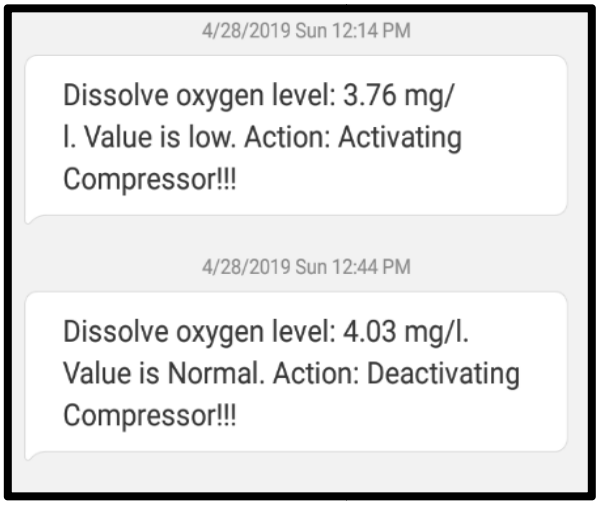


Figure 5. Text Message

Figure 5 shows the test message the fish cage owner received when the bubble aerator was activated.

Summary of Findings

The following are the findings obtained after the design the development of the Modified Solar Powered Bubble Aerator.

1. The existing Solar Powered Bubble Aerator consisted of using two 100 watts solar panels connected in series to harness solar energy

connected directly to the 20A solar charge controller, which regulates the voltage that being stored in the batteries. The Two-12VDC batteries are connected directly to the 1000 watts pure sine wave inverter and the ¼ HP air compressor is connected directly to the inverter. A 24VDC smart relay connected in the load terminal of the charge controller serves as the switching device in the battery-inverter connection. A time switch was used to switch on the smart relay in the desired starting time of the program. The smart relay controls the duration of switching of the four-24VDC solenoid valves.

The fabricated cabinet was constructed with 120x50x120 cm dimensions and was installed on a 10m x 10m x 10m fish cage. The fabricated cabinet was divided into three sections. The inverter, solenoid valves, smart relay, time switch, charge controller were in the same room for better wiring. The battery was separated to a different room of the cabinet to prevent sulfuric acid emitted not to cause damage on other components and the air compressor was installed on the lower room for better ventilation. Construction layout is composed of different views that display the whole structure with its component and dimensions. The different views include the perspective, front, left and right side view.

The existing bubble aerator used a smart relay to execute the switching time and operating duration of each solenoid valve. The solenoid valves were used to control the passage of the air in the discharging process of the air compressor. A time switch was used to set the switch on the smart relay together with the program of the sequence of the operation of the solenoid valves on the desired time the end-user requested, which was from 12 o'clock midnight to 6 o'clock in the morning, the process of diffusion of air from the compressor was happening.

The present researchers found a way to modify the existing project. The areas to be modified was the time of aeration. By installing a temperature sensor and dissolved oxygen sensor, the bubble aerator will only work when the measured values of temperature is too high and the dissolved oxygen is too low. Moreover, a GSM module to send SMS to the fish cage owner about the values of the temperature and dissolved oxygen of the water. The existing project uses a many electrical components that requires a lot of power to operate but the project runs with solar panels and batteries, we can eliminate the unnecessary usage of power by using electronics components that consumes low electricity. And with the introduction of electropneumatics system in the solenoid valve, the Arduino Mega can communicate faster to the solenoid valve installed to the compressor to release air.

2. The PEC provided standards that gave instructions on sealed cells and multi-compartment batteries constructed of non-conductive, heat-resistant materials and shall not require additional insulating support. Article 4.80.19 indicated battery locations should conform to ventilation. PEC also covered regulation on Module Connection Arrangement.

The IEC provided the standard on conductors of insulated cables and requirements for numbers and sizes of wires and resistance values are included.

The IEEE provided the standard for relays and relay system associated with electric power apparatus. Particularly, Relay with input of 5 V DC and a load of 20A, 240V AC, 50Hz/60Hz should be used in electronic devices.

The NEMA provided the standard for the enclosures according to the types of applications the enclosure serves. The NEMA rating is assigned to describe protection against environmental hazards such as water, dust, oil, or hazardous areas that contain corrosive or explosive climates.

The BFAR provided the standard for the milkfish living conditions along with the right

temperature and dissolved oxygen of the water. Milkfish are Eurythermal meaning it has a wide temperature tolerance range (10- 40°C) with optimal growth ranging from 25-30°C Water temperature – affects metabolism of fish and consequently growth rates; optimum temperature is 25-32 °C; growth is reduced at 23 °C. High and stable dissolved oxygen level of water (7-8 ppm).

The DENR provided the water quality guidelines that shall be maintained for each water body classification. The Class C Water Body Classification for Fishery Water for the Propagation and Growth of fish and other aquatic resources. Which is the Minimum Dissolved Oxygen must be 5 mg/L and Temperature should range from 25-31°C.

3. The project consists of Arduino Mega, GSM Module, dissolved oxygen sensor, temperature sensor, solar panels, battery, inverter, solar charge controller, and solenoid valve and air compressor. The solar panels were used as an energy source connected to the solar charge controller then to the battery to store the energy. The temperature sensor and dissolved oxygen sensor measures the temperature and amount of dissolved oxygen in the water respectively. And Arduino Mega acts as the brain of the system. The GSM Module was responsible in sending a text message to the owner of the fish cage about the status of the project and the measured temperature and oxygen. The inverter converts the DC voltage from the battery to AC voltage to power the air compressor. And the solenoid valve was used to diffuse air from the air compressor.

4. Computations and analysis were made in determining the design of the project especially the rating of the battery. The battery used was a 200Ah lead acid battery. Which was used to power the electronic components and the air compressor. Proper computation for the number of solar panels were also made. And the pressure underwater was also calculated to determine the minimum gauge pressure of air was needed to produce bubbles under water, the computed pressure was 14.23 psi.

The project design's layout was prepared and understood through the use of schematic diagram. Which clearly showed and simplified the flow of the process and showed more detailed connection of each component. The schematic diagram helped in making and the construction of the project.

The modified solar-powered bubble aerator used Arduino Mega Microprocessor to execute its program of operation. The dissolve oxygen sensor and temperature sensor were the input devices. Which measures its respective values, then if the values are not within the normal range the GSM module will send a message to the owner about the measured value then energize the solenoid valve to diffuse air from the compressor.

5. The bill of material and specification of the solar powered bubble aerator was also considered in the undertaking of the proposed project. The total cost of the project is Php 78,580.00.
The overall financial aspects were calculated to foresee the financial prospects for the project. The total amount of the project is Php 78,580.00. It is the sum of all the materials was used in the project and the program for the Arduino Mega. The annual depreciation of the project is Php 7,858.00. The lead acid battery and the dissolved oxygen sensor were the most expensive components for the project and were secured properly to avoid any problem that may occur. Based on the computation, it will take almost 1.25 years to recover the investment. This proves that the investment was profitable.

6. The methods of fabrication, assembly and installation were followed such as preparations of materials and tools to guarantee the correct design and achieve the needed output of the

project, to ensure its' functionally and to minimize the errors.

The tools used were multimeter, bolt, nut and washer sets, set of screw drivers, set of pliers, soldering iron, electrical tape, rubber tape, connecting wires and cable tie. The researchers used the materials based on the prepared design plan, schematic diagram and installation procedures.

The test done on the prototype were divided into name: Charging and Discharging Test, Aeration test, and Functionality Test. The procedures were followed to ensure accurate results of the project.

Through the charging and discharging test, the voltage generated in every trial means that the battery is charging. In the charging and discharging test, it was shown that from the six hours of charging the voltage of the battery was the highest and the battery charge is enough to run the compressor for two hours straight. The full charge voltage was 12.4 V while the lowest voltage recorded was 10.5 V. In the aeration test, it was shown that the higher the pressure applied to the air coming out of the compressor, the better the improvement on the Dissolved Oxygen values in the water. The lowest dissolve oxygen value measured was 6.04 mg/L, with the highest increase of .56mg/L of Dissolve Oxygen in just one hour of aeration. And in 100 psi pressure the average increase of dissolve oxygen was .228 mg/L•hr in the whole fish cage. In the Functionality Test, it was shown that the program of the Arduino Mega was properly working. However, the GSM Module must use a TNT sim card for better sending of the text message with the message delay of 2 seconds. The lowest dissolve oxygen measured was 2.74 mg/L at 5:17 AM. The running time of the project was usually during early morning, noon and late afternoon, where the dissolve oxygen were low and the temperature were high.

7. The project would be a great help in terms of financial and time aspects. Instead of suffering fish kill and investing money to recover from the natural phenomena, the prototype will provide the solution to fish kill. A milkfish fish cage houses 20,000 pieces of milkfish fingerlings and after 8-12 months, when it is already harvestable approximately only 15,000 pieces survived. Using the prototype, the owners can increase the number of surviving milkfish thus, increasing the income for the Manalao Fish Ville.

CONCLUSIONS

Based on the findings, the following conclusion are made:

1. The existing Solar-Powered Bubble Aerator used many electrical components that consumes extra power from the batteries. Moreover, the aeration time of the existing project was severely limited to the time frame, and no flexible enough to respond to a change in temperature and by installing a temperature sensor and dissolved oxygen sensor the aeration capability of the previous project will improve. Moreover, a GSM Module was used to inform the fish cage owner about the status of the water quality.

2. The compliance to requirements and considerations from Philippine Electrical Code (PEC), National Electrical Code (NEC), International Electrotechnical Commission (IEC) and National Electrical Manufacturers Association (NEMA), Bureau of Fisheries and Aquatic Resources (BFAR), and Department of National Resources (DENR) standards were highly considered to ensure the safe operation and functionality of the project.

3. Preparing and having the right project design from the layouts, circuit diagram, and the design computation and analysis greatly helped in the success of the project. It reduced the time of fabrication wiring and installation and at the same time, provided the efficiency of the project.

4. The project is worth its investment. The project will bring more income to the Manalao Fish Ville by preventing fish kills.

5. The essential of the project development is following the methodology prepared and

determination of right materials and tools. It is necessary that all the materials used are available in the market and follow the preparation plan to ensure the reliability and performance of the prototype. Safety precautions, use of proper equipment and testing of components are measures which made the fabrication of the project feasible.

6. The location of the Solar Powered Bubble Aerator and the time of the day are important to maximize the solar energy harvesting and to maximize its use during its operation. The duration which the Solar Powered Bubble Aerator will operate depends upon how long its batteries are charged. The use of a higher pressure to aerate the fish cage is important. In addition, the use of the right sim card to be used on the GSM Module is important.

7. The project study promoted the sustainability of the water quality at Taal Lake by using aeration process. It could affect the economy because it prevents fishkills that increases income. It is considered a good investment. The project has benefited both the society and economy.

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