Design of Solar Powered Vertical Aquarium Filtering System for *Clarias Gariepinus* (African Catfish)

May C. Layson, Christian N. Pineda, Nilo Q. Manuntag

Abstract*: Fish production in Pangasinan specifically fish farming is mainly monopolized by people with financial capabilities. Local farmers work for these people or rely mainly on working with these capitalists. NIFTDC BFAR Dagupan conceptualized vertical farming for small scale fish farmers. However, these fish condo consumes local grid power and Dr. Westly Rosario of NIFTDC BFAR Daugupan aimed to help these farmers even without local grid supply. A design of solar powered aquarium was developed to respond to this need. The design system uses solar panel as its source. Computations show that a 400-watt solar panel can supply the system load including the motor pump. Charging and discharging time of the battery were also determined. Maximum panel output was also suggested following the optimum tilt per month. An automatic water filtering system was also included that measures both dissolved oxygen and pH level of the water inside the culture chambers. Nominal values of pH and dissolved oxygen were set to automatically normalize these values according to the appropriate aquatic living conditions of African catfish. An ROI of 0.14 and payback period of 7.84 were determined. Computations were based from the capital investment of BFAR Dagupan. Growth and yield rate of African catfish are expected to improve in the application of the system to the vertical aquariums.

***Keywords*: Solar panel, Vertical Farming, African Catfish, dissolved oxygen**

I. INTRODUCTION

There is a need to address the worldwide concern for food production brought about by the continuous increase in world population experiencing poverty and hunger especially in developing countries. Agriculture, aquaculture and fisheries are the main sources of food production. However, because of overfishing and other abuses, the world's natural sources of fish are unable to sustain people's needs [1]. A solution seen for this scarcity is the development and utilization of aquaculture [2].

Marine aquariums are one way to help manage fish production. A number of marine aquariums are used around the world. One challenge in maintaining one is providing sustainable oxygen for the marine life. In closed circulating marine aquarium systems, the effectiveness of the purification of water through filtration can be measured by oxygen consumption. The oxygen consumption data can be used to determine the balance between purification and this index was used to investigate the balance between purification and pollution of the culture water as well as to determine the capacity of marine aquarium against the number and total weight of fishes to be cultured therein. Water tends to exhibit some characteristic changes in chemical composition along with the lapse of time even if culture water polluted by excretion of fishes and by feeding may be purified by filtration through sand [3]. Dissolved oxygen in water must be available for consumption for fish and other organisms for life substance. Ideally, a body of water should have 5.7 mg/l of dissolved oxygen to sustain life [4]. Polluted water will have dissolved oxygen that can be less than 1 mg/l because microorganisms feed on it [5].

[6] noted in her study that Asian catfish has become a popular epicurean inclusion to the Filipino diet because of its tender and delicious meat. This encouraged more farmers and fish capitalists to invest in catfish farming. Due to their characteristics such as resistance to diseases, can be stacked at high densities, and can tolerate low water quality, aquamarine scientists recommend catfish farming can be stocked at high densities, and can tolerate low water quality. In Thailand, 100,000 small fingerlings (1.5 inch size) were stocked for a pond area of about 1600 m2. This leads to a density of 62 fingerlings/ m2 [7]. The effect of stocking density on growth, production and body composition of Clarias gariepinus and Heterobarnchus longifilis were also studied by Toko [11] in West Africa where traditional whedos were constructed as fish ponds. The study proved that African catfish (C. gariepinus) can be grown at high densities rather than the vundu catfish (H. longifilis). Mortality was not significant for the African catfish even if it reached the critical density at 8 fish m-3. Thus, this stocking density gave the highest net benefit and best benefit cost ratio. It was also proven that the two catfishes can be efficiently grown in whedo for 75 days and can generate 3 5 t per hectare. The National Integrated Fisheries Technology Development Center (NIFTDC) under The Bureau of Fisheries and Aquatic Resources (BFAR) in Dagupan, Pangasinan is looking for a solution on how its local fish farmers in areas without electrical supply to still make a living in fish farming. Moreover, they also want to make this type of business possible without investing much on fish ponds. Dr.

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Wesley Del Rosario [10] of NIFTDC primed the vertical farming which uses big containers as ponds for catfish. The limitation of the existing ponds is its power source since it uses AC to power up motors for water circulation.

As a solution solar powered vertical aquarium was designed. Solar energy is the main power source of the project, backed-up by a battery. Theoretically, during daytime the solar panel will run the system using the converted solar energy. In addition, the back-up battery will also be recharged. A water pump will be used to prevent the water from being stagnant. The system design uses Arduino Uno Microcontroller to perform the control functions like turning ON and OFF of the water pump. The system will also have a dissolved oxygen sensor that will measure the oxygen level of the water and a pH sensor to measure the acidity of the aquarium water.

The design can filter the circulating water of the aquariums through a filtering system located on the top of water drums similar to fish aquariums connected side by side and stacked vertically through metal beams Figure 1 shows the adapted design from NIFTDC Dagupan.

The structural design is composed of gravel & filter box, 3-level aquarium and pumping system. The dimension of the filter box is 1.5 m x 1.5 m x 0.3 m. Gravel, pebbles, sand, netting materials and charcoal is used in the filtering process. Metal bars with 16mm thickness are used in the chassis. The dimension of the chassis is 2.3 m x 1.8 m x 3.0 m. 14 Metal drums are used as culture chamber. Each drum has a capacity of 200 L of water. Polyvinyl chloride (PVC) pipes are used as part of the water circulation and filtration system where solid wastes are trapped allowing the monitoring of waste level in the drum compartments. 0.5 hp DC motor pump is used to recirculate the water system in the fish condo. Solar panels with charge controller and deep cycle batteries are used as the main source of power of the dc motor.

Figure 1. Fish condo (designed by Dr. Westly R. Rosario crafted by BFAR-NIFTDC).

The main objective of the study is to design a power supply system that will help local fish farmers build their own aquarium with filtering system that uses an alternative source of energy.

The study is focused on the design of the power supply system of the aquarium. Control system is also included in the system. Two 270-watt solar panels connected in parallel will be utilized, in harvesting energy to charge the two 100 Ah deep cycle 12v battery. The charging of the battery will be controlled by a 30A charge controller. As the battery gets charged its 12 VDC output will be inverted by a 1000 watts pure sine wave inverter into 220 VAC, which will be used as a load to operate the 100 watts water pump. It was designed to pump the dirty water up to the sand bed for filtering. The systems Feeder alarm, relay switch, and dissolved oxygen (DO) sensor will be controlled by a Microcontroller unit.

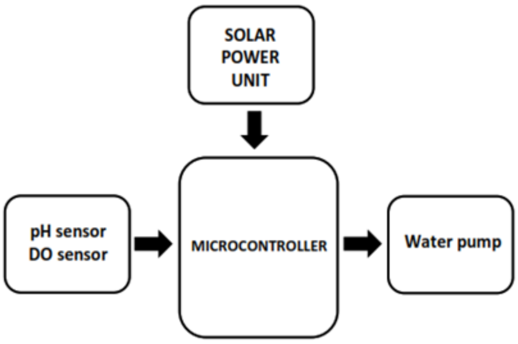

Figure 2. System Design

Since the study is limited only to the design, the following delimitations were of consideration: (a) the system only filters the circulating water of the aquariums; (b) the water pump cannot run 24 hours a day; its operation will depend on the oxygen level that the D.O sensors detected. It needs to be shutdown to prevent overheating and for the battery to get charged; (c) the aquarium in this system is 0.66m in diameter and 0.97m in height and can contain water for up to 200L; (d) for every meter2 there must be 36 catfish fingerlings per cultured chamber, and the area of each container is 5.5m2 so that each container must only contain 200 catfish fingerlings and (e) the water pump must get cleaned once a week for maintenance.

II. METHODOLOGY

A. System Power Requirement

Table 1 shows power loads identified from the design to determine the total power required to run the system. Two LED bulbs were included for aquarium area illumination. A 392-watt total load was calculated. This computed value is the reference in determining the power supply system specifications.

Table 1. Total System Load

QTY	EQUIPMENT	POWER RATING (watt)	TOTAL POWER (watt)
1	0.5 hp submersible pump	384	384
1	Arduino Uno	1	1
1	DO Sensor	1	1
1	pH Sensor	1	1
2	11 – watt LED bulb	11	22
1	60 A MPPT Charge Controller	2.5	2.5
		TOTAL	**391.7**

B. Power System Design

The power system design is based on the computed total power system requirement. The main power source of the system will be coming from two Lithium Ion batteries.

These batteries will be charged during daytime through the solar panels.

To obtain maximum panel output, optimal tilt [8] of the solar panel is considered. He derived formulae for optimal angle of solar panels throughout the Philippines. Monthly country average values and fixed-mount of solar panel tilting formulas were also derived.

The following were considered in the solar panel tilting computations:

January: 0.734899 (latitude + 23.4) = angle from horizontal
February: 0.835051 (latitude + 15.6) = angle from horizontal
March: 0.952525 (latitude + 7.8) = angle from horizontal
April: 1.024192 x latitude = angle from horizontal
May: 0.932828 (latitude - 7.8) = angle from horizontal
June: 0.827929 (latitude - 15.6) = angle from horizontal
July: 0.775404 (latitude - 23.4) = angle from horizontal
August: 0.742929 (latitude - 15.6) = angle from horizontal
September: 0.776667 (latitude - 7.8) = angle from horizontal
October: 0.749899 x latitude = angle from horizontal
November: 0.713889 (latitude + 7.8) = angle from horizontal
December: 0.679192 (latitude + 15.6) = angle from horizontal

The orientation of the solar panel mounting is based on the computed angle. When the value of the angle is negative, solar panel must be facing north from horizontal. When the value of the angle is positive, the angle of the panel must be facing south from horizontal.

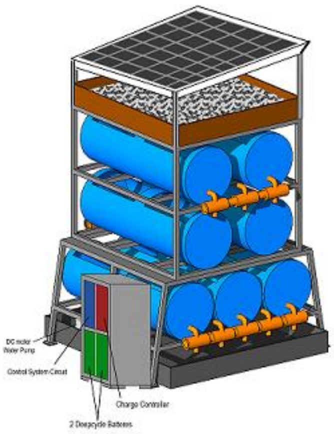

Figure 3. Physical Lay-out of the System

If fixed-mounting is used for solar panel mounting, the country annual average results to a 0.812 correction rate. The angle can be computed using the formula:

0.812117 x latitude = angle from horizontal facing south

C. Control System Design

The system is installed with dissolved oxygen sensor in the lower level of the fish condo to detect the current amount of DO in the aquarium. This sensor is connected via the Arduino Uno microcontroller that serves as the central processing unit of the system. Once the DO sensor measures below the nominal level, the Arduino Uno will turn on the water pump for the water circulation process. This process will replenish the required DO level of the fish condo aquarium. Once the dissolved oxygen reaches the normal level, water pump will turn off. The Liquid Crystal Display exhibits the required DO level of the system.

On the other hand, a pH sensor is also included in the system to measure the pH level of the aquarium's pH level. Once, this level reaches a value greater than 6.5. This allows the replenishment process for the circulation of the water from the tank to the filter maintaining the required dissolved oxygen and pH level inside the aquarium.

These sensors are connected in the system in such a way that whichever needs replenishment first will trigger the water pump to turn on.

III. RESULTS AND DISCUSSION

A. Panel and Battery Sizing Computations

A.1 Panel Sizing

For a power load requirement of 391.7 watts, 400 watt solar panel is required

The culture chambers require 2800 liters of water and the water pump capacity is 3000 liters per hour. An average of 0.93 hour of motor pump operating time is obtained to replenish the culture chambers with filtered water.

Battery Ampere - Hour Rating = (Power Load / Battery Voltage Rating) (Operating Time) (2)

= 391.7 watts/(12V)(1 Hr)(2)

= 16.32 Ampere-Hour

The basic battery size is multiplied by 2 to determine the safe battery size [9].

Charging time can be calculated by:

Charging Time of Battery= Battery Rating (Ah) / Charging Current (Amperes)

Charging Current = Solar Panel Power rating / Load voltage

Charging Current = 400 W / 24 V

Charging Current = 16.667 A

Charging Time of Battery = 100 Ah / 16.667 Amperes

Charging Time of Battery = 6 Hours

Discharging Time of Battery

Discharge Time = Battery Rating (Ah) / (Power Load (in Watts)) / Rated Voltage of the Battery (in Volts))

Discharging Time (in Hours) = 100 Ah / (391.7 Watts / 24 Volts)

Discharging Time (in Hours) = 6.127 Hours

B. System Simulation

B.1 Program simulations

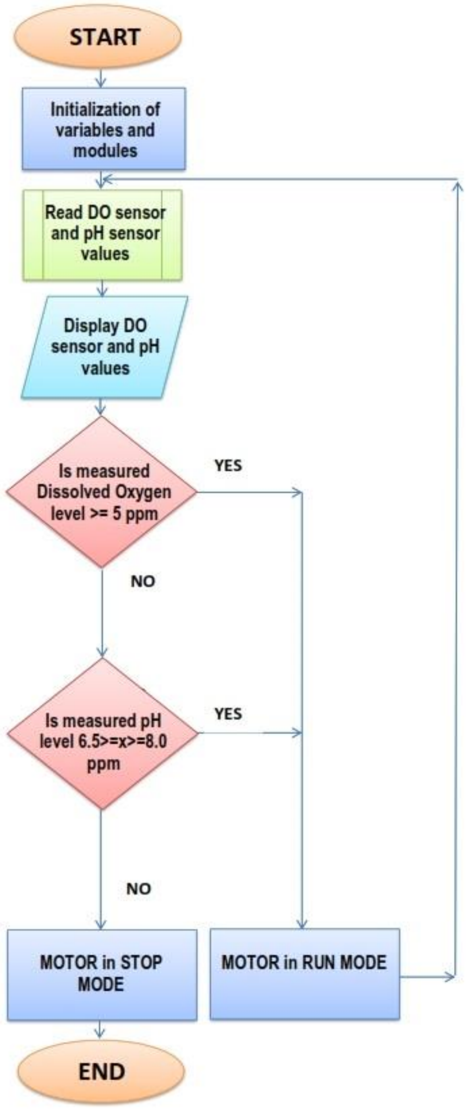

Figure 5. Flow chart of the System Control

Based on the design requirements and through a simulated program using Arduino Uno Microcontroller, the flowchart in Figure 5 highlights the flow of the system design, especially the control of the motor through the input from the values of the DO and pH meter fed to the microcontroller. DO and pH values are detected by the sensors and are compared to the set nominal values. The nominal value for pH and DO level are 6.5 to 8.0 and 5.0 ppm respectively (Potangkam and Miller, 2006). These values are the input for the microcontroller to turn on or off the motor. Once the motor turns on, it is an indication that the pH exceeds and or DO level deficits their nominal values.

To obtain a maximum panel output, Table 2 suggests the tilting angle for each month of the year for optimal exposure of the panels obtaining maximum possible output every month. For fixed mount tilting position the panel should be tilted 0.812117 X 16° 2' 51" = 13°1'56.81" from horizontal facing SOUTH [8]

Table 2. Computed Panel Optimal Tilt For Dagupan, Pangasinan [8].

MONTH	TILT ANGLE
January	28°59'23.74" from horizontal facing SOUTH
February	26°25'38.2" from horizontal facing SOUTH
March	22°42'55.22" from horizontal facing SOUTH
April	16°26'8.6" from horizontal facing SOUTH
May	7°41'36.6" from horizontal facing SOUTH
June	0°22'13.79" from horizontal facing SOUTH
July	5°42'4.17" from horizontal facing NORTH
August	0°19'56.85" from horizontal facing SOUTH
September	6°24'20.02" from horizontal facing SOUTH
October	12°2'2.42" from horizontal facing SOUTH
November	17°1'28.08" from horizontal facing SOUTH
December	21°29'41.02" from horizontal facing SOUTH

Cost Analysis and ROI

The system costs Php 43, 717 which will be included to the capital outlay of Php 45,815 already invested initially by BFAR. Payback period is 7.84 months while the Return of Investment (ROI) is 0.14. This computation however does not consider the survival rate of the catfish. Previous calculations are much lower but the system uses AC as power source and since the aquariums are replenished from time to time, growth of the catfish is promoted, thus higher yield is expected.

IV. CONCLUSION AND RECOMMENDATION

From the computed data, the system has a longer payback period of 7.84 months. However, survival was not considered since it is an initial design and was not yet tested in actual setting. Return of Investment is 0.14 but will decline in the succeeding harvests since electrical costs will be eliminated in the production cost. An additional light dependent resistor (LDR) for night switch can be added to automate the system during the night. A 5min/hour run time for the motor pump for every one hour interval or an average of additional one hour to the total operating time of the motor can be included in the power consumption of the system per day for night time operation. Testing the system in actual is recommended for verification of the design. A solar tracker can also be included to automatically tilt the solar panels for optimal output.

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