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Analysis of a Solar PV System for Aeration System in Aquaculture

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ABSTRACT
Artificial fish ponds harvester often face the problem of lacking the oxygen content in ponds. If there is too much oxygen, fish can even get sick. This will result in a great reduction of income for fish harvesters. Solar aeration can play a vital role in improving the water quality by removing dissolved gases. This aeration system can be applicable where electricity is not available .This paper discusses the feasibility of solar aeration system in rural places of Bangladesh. Homer software was used to simulate the aeration system for small scale ponds of a place called Godagari, Rajshahi. It was found that the optimal sizing of photovoltaic 2 kW, 2 battery of 400 Ah and inverter of 0.6 kW and Cost of energy is about 0.463 $/kWh which is 37.04 taka in BDT (1 US=80).

Keywords: Aquaculture; Solar aeration; Homer.

1. Introduction

Aquaculture provides food security to more than 20 million people worldwide [1]. As one of the fastest growing industries in the world, it maintained an annual rate of 7% between 1970 and 2000 and 6.2% between 2000 and 2012 [1].In developing countries, such as Bangladesh fish forms a staple diet obtaining 57%of their protein intake from fish [2]. Between the period 1985- 2013, aquaculture grew at a rate more than twice that of marine and capture fisheries, contributing about 45% of Bangladesh’s total annual fish production [3]. So, this industry is a major economic driver contributing to 4.4% of the GDP in Bangladesh [4].About 73% of rural people are involved in fish farming practice [5].

People in rural area of Bangladesh is suffering from extreme hardship and poverty. In order to reduce rural poverty rate, Bangladesh government has turned to aquaculture, a way of meeting the nutritional needs of the rural poor, a fifth of whom are suffering from chronic food insecurity and malnutrition [6].Government’s efforts have resulted in promoting small scale form of aquaculture. According to a report, about 20% of rural households have a homestead pond, covering a combined area of 265,000 hectres [7]. Farmers operating these ponds do not have any technical knowledge. Besides, these ponds are used for multipurpose process. As a result water quality becomes bad and it hampers fish productivity.

This paper is an attempt to check the feasibility of solar aeration for a place called Godagari, Rajshahi. Mathematical modeling has been done to find the no of solar modules and capacity of battery. Simulation is performed on Homer software to find the feasibility of the system. This study is developed from the reference no [8].

2. Aeration

Air contains approximately 20.95% oxygen. The pressure of oxygen in the atmosphere drives the oxygen in the water until the pressure of oxygen in the water is equal to pressure of oxygen in the atmosphere. When these pressures are equal, the water is said to be equilibrium with dissolved oxygen (DO). Several factors such as temperature, salinity affect dissolved oxygen concentration. When water contains more DO than a specific level for a given temperature and pressure, the water is called supersaturated. Water may also contain less DO than saturation. It may be happened at night as this is the period when oxygen content is low. At night dissolved oxygen declines due to respiration of plants, fishes and other pond organisms. In production ponds, DO may decrease by 5–10 mg l^{-1} at night, and in un-aerated ponds, DO concentrations at sunrise may be less than 2 mg l^{-1} .The less percentage of dissolved oxygen can severely affect aquaculture [9].

The process of bringing water and air into close contact by exposing drops or thin sheets of water to the air or by introducing small bubbles of air and letting them rise through the water is called Aeration. Aeration is done by aerators. Aerators are generally two types; splashers and bubblers. Aerator improves water quality by mixing oxygen from atmosphere to water. As a result, dissolved oxygen content increases [10].

3. Cost for Different Types of Aeration System

There are mainly three types of aeration system such as: solar, windmill &electric aerator. The cost of a aeration system is determined by a combination of up front capital investment, annual operating costs, annual maintenance costs and projected life expectancy. Capital investment can be low as $ 500 for a shallow pond while it can be high as $8000 for a large

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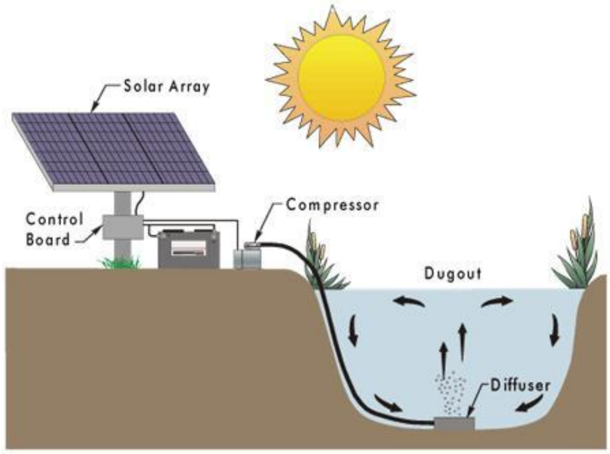
aquaculture [11]. Operation cost is determined by the number of amps needed to power an electric motor multiplied by the electricity cost in the area [11]. Table 1 shows the capital investment(CI) , average annual cost(AOC), average operation cost(AC), annual maintenance cost (AMC) and life expectancy(LE) of different aeration system [11].

Table 1: Assessment of different cost and life expectancy of different aeration systems.

Aeration systems	CI $	AOC $	AMC $	LE Years	AAC $
Electric	750	180	35	4	402.50
	1500	240	35	5	575.00
	2500	240	35	5	775.00
Solar	2995	0	50	10	349.50
	6500	0	50	10	700.00
Windmill	1500	0	75	20	150.00
	2500	0	75	20	200.00
	3500	0	75	20	250

4. Solar aeration

Solar aeration system consists of solar arrays (solar panels) that convert sunlight into Direct Current (DC) electricity. Then it can be used directly or stored in batteries for use at night or on cloudy days.



When the sun shines, charges are stored on battery. The battery powers a compressor that forces air through a diffuser at the bottom of the pond. Here in figure 1 arrows indicate that, the movement of air throughout the entire volume of water.

Solar aeration system consists of:

1) Solar panels (sized to supply enough power for calculated consumption)
2) Batteries to store excess power
3) Compressor
4) Inverter
5) Air diffuser
6) Weighted feeder hose

It is same as electric aerator except solar power acts as its power source.

5. Design procedure

The whole procedure of PV system sizing is given below

- Load Calculation
- Assess solar resource
- Select days of autonomy
- Size battery bank
- Size module array

5.1 Load calculation

Aeration is necessary when oxygen content is lower in the air. So aeration will be needed in the evening. Here the time period considered from 10 p.m. to 6 a.m. Table 2 shows load calculation for Godagari.

Table 2: Load calculation

No	Utilization	Power	Value (unit)	Working time	Energy demand (kwh)
1	Diffuseror blower	70W	1	8 hours(10 p.m.-6 a.m.)	0 .560
2	Indoor lighting	20W (CFL)	2	4 hours(6 p.m.-10 p.m.)	0 .160
3	outdoor lighting	20W (CFL)	4	12 hours(6 p.m.-6 a.m.)	0 .960
					Total= 1.680 kwh

So the daily load is 1.680 kwh.

5.2 PV system sizing

For solar resource we have considered a place called Godagari (24°28′N 88°19.8′E).It is an Upazila of Rajshahi district. This place's scaled annual average solar resources are 4.8 kWh/m^2/d[13]. Figure 2 contains the daily radiation of Godagari.

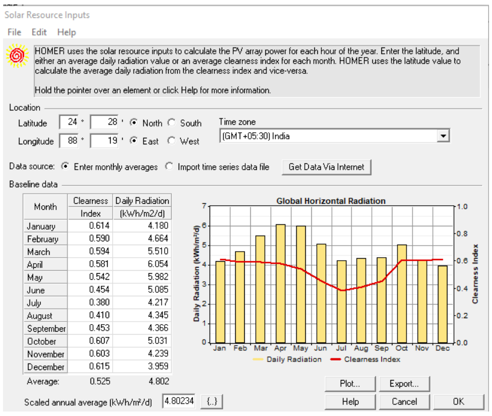


Fig. 2: Daily radiation of Godagari [9]

From the Figure 2, it can be seen that the least unfavorable month for solar radiation is December (3.95).Now calculating peak solar hour (PSH) for the worst month is 3.95h/day.

Here peak solar hours are the no of hours of $1kW/m^2$ irradiance that would yield the same amount of energy.

Now the system comprises of

1) PV
2) Cables
3) Charge regulator
4) Battery
5) Inverter
6) Load

So, the required power (for PV) is

P_{PV}= (Load) ÷ (n_{bat} *n_{reg}*n_{inv}*n_{wir})

= (1.6 kWh/day) ÷ (0.61)

=2.62 kWh/day

Assumption:

Battery efficiency, n_{bat}= 80%

Inverter efficiency, n_{inv}= 90%

Wiring efficiency, n_{wir}= 95%

Charge regulator efficiency, n_{reg} =90%

Peak power (P_{peak})

=P_{PV} ÷ (PSH)

= (2.62 kWh/day) ÷ (3.95 h/day)

=0.67kWp

String length

Operating voltage V_{DC}=48 V

Module voltage V_m=12 v (assuming: string with four module)

String length is $N_s=V_{DC} \div V_m$

=4

No of strings

(Assume 50wp module)

$N_P=P_{peak} \div (N_S*P_M)$

=0.67kWp ÷ (4*50)

=3.35 ~ 4

So the total no of modules are

$N = N_S*N_P = 4*4 =16$

So the required area A= N*A_m

=16*0.4 (Assuming per module area is $A_m=0.4m^2$)

=6.4 m^2

Battery Capacity (C_B):

C_B= (DOA*load) ÷ (DOD)

Here,

DOA is days of autonomy

DOD is depth of discharge

Days of autonomy is the no of consecutive days without being recharged a battery bank can provide energy to the load. It would be slightly less than the maximum no of continuous cloudy days for the site.

When selecting a battery depth of discharge is the one of the key figure that should be considered. DOD is the rate how deeply the battery is discharged.

Assuming DOA is 5 days and DOD is 0 .7

$$\text{Battery capacity } C_B = \frac{5\times(\frac{1.6kwh}{day})}{48volt\times 0.61} \div 0.7$$

=392 Ah

6. System Modeling

The system considered here is an exemplary model for fulfilling the energy demand for Godagari. The system consists of PV array, Battery, Inverter and electrical load. HOMER Software is used for modeling where capital cost, replacement cost and O&M cost for each component has been considered as input parameters.

6.1 PV Array

2 kW PV panels have been considered here. The capital cost of 1KW panel is considered to be $500.00 and replacement cost is $500.00 with operating and maintenance cost of $10.00 per year. Life time of each panel have been considered 25 years with derating factor of 80. Figure 3 shows the PV inputs in Homer.

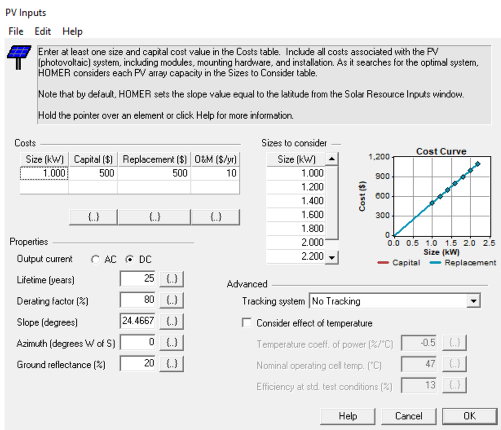


Fig. 3: PV inputs in Homer

6.2 Converter

DC to AC converter of 0.6 kW has been considered in the simulation. The capital and replacement cost for per kilowatt is considered here to be $79 and $79 respectively with O&M cost of $5 per year. The lifetime is considered 15 years with 90% efficiency. Figure 4 shows the converter inputs of Homer.

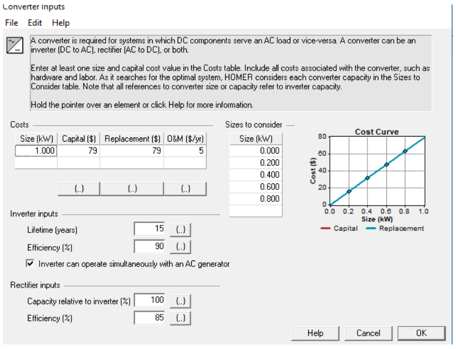


Fig.4: Converter inputs in Homer.

6.3 Energy Storage

For energy storage batteries have been considered in the simulation. The Model used is USB-US 305 with nominal capacity of 400 Ah and throughput is considered to be 673.20kWh. The capital and replacement cost is considered to be $450 and $350 respectively. The O&M cost is considered $5.000 per year.

7. Result

From Figure 5, it can be seen that the optimal sizing of photovoltaic 2 kW, 2 battery of 400 Ah and inverter of 0.6 kW and COE is about 0.463 $/kWh. Here COE is quite high. It may be due to lack of availability of components in that proposed location. Lack of availability of components result in high cost.

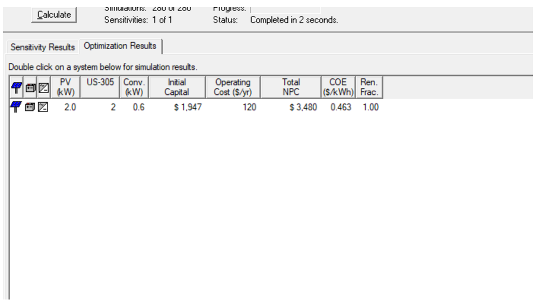


Fig. 5: Simulation result

8. Conclusion

In this paper, a design optimization of solar powered aeration system for a small-scale of fish pond by HOMER software is presented. This system meets the feasible demand of1.60 kWh/day load by Photovoltaic 2 kW, 2 battery of 400 Ah, Inverter 0.2 kW when COE is about 0.463 $/kWh. Solar aeration can be a useful method in improving the quality of water in Bangladesh. Many farms which suffer loss due to bad water quality can use this method to improve not only the water quality but also improve the productivity of fish.

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