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A PORTABLE PHOTOVOLTAIC WATER AERATION SYSTEM

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ABSTRACT

Water aeration is a method to improve the water quality in a lake by adding oxygen to the water. Because water aeration systems are often located in remote locations, photovoltaics are ideal for powering these systems. This paper describes a water aeration system powered by photovoltaics that is used in Florida. The portable nature of this system permits the owner to conveniently relocate the system and aerate bodies of water as needed.

KEYWORDS

Photovoltaics; water aeration; air compressor; linear current booster; photovoltaic system design.

INTRODUCTION

The Florida Solar Energy Center, through a cooperative program with the Florida Governor's Energy Office and Lee County, Florida, recently developed the guidelines and specifications for a water aeration system to be used by Lee County. The rapid growth of Lee County has adversely affected the water quality of some of their wetlands and lakes because of organic runoff, silting, and water stagnation. These factors cause the water to become eutrophic, a condition marked by a lack of oxygen in the water.

Although chemical treatments of lakes using herbicides can be an effective method to improve the oxygen content of the water, they are detrimental to the aquatic life in the lake. An aeration system is the preferred method to introduce oxygen into the lake. An air compressor supplies air to a diffuser several feet below the surface of the lake. The diffuser breaks the air into small bubbles that rise to the surface of the lake. Small bubbles promote efficient oxygen transfer to the water. The flow of air bubbles to the surface also circulates the lake water, making the lake a healthier environment.

Because aeration systems are often needed where there is no utility power available, photovoltaics (PV) are an ideal way to meet their modest energy requirements. The high reliability, low maintenance, and minimal operator intervention of PV systems is also a distinct advantage over gasoline or diesel-powered aeration systems.

This paper provides information on the design criteria established for the portable aeration system, a description of the system as procured, and its operating characteristics.

DESIGN CRITERIA AND SYSTEM DESCRIPTION

Lee County requested that the aeration system be powered by PV, be reliable with minimal operator intervention, fit in the back of a pickup truck for portability, and be installed on a float so that it can be easily relocated to different parts of the lake. For this system, the PV modules are connected directly to the dc air compressor motor. This eliminates the need for batteries and charge controllers that may reduce the reliability. The aerator system introduces oxygen into the water with a diffuser suspended below the float. This is one method of water aeration. Water aeration achieved by splashing is another method that has also been used (Ward and colleagues, 1989).

For the purpose of procuring the PV-powered water aeration, specifications were developed pertaining to the system performance, reliability, and safety. The specifications and requirements for the different system components, and the electrical and mechanical design are summarized in the following paragraphs.

Air Compressor with DC Motor

The air compressor and DC motor must be rugged, durable, and of materials suitable for an outdoor installation in a wet, humid, and hot environment. The design air requirement is for the air compressor to provide 1.0 cfm of free air to a depth of 15 feet below the surface of the water. For this flow rate, the air compressor must develop sufficient pressure to overcome the static pressure due to water depth and the frictional losses in the hoses, couplings, check valve, and diffuser. (With the proper selection of components, the total pressure head is about 10 psi for this installation.)

Photovoltaic Modules

As an indication of reliability in terms of electrical performance and the ability to withstand

severe mechanical cycling and loading, the PV modules must meet JPL Specification Document No. 5101-162 entitled: "Block V Solar Cell Module Design and Test Specification for Residential Applications - 1981", or equivalent tests.

The PV array is sized to meet the electrical load requirements when operating with a plane-of-array irradiance of 800 W/m^2 and a PV module temperature of 55 degrees C. The electrical load is defined as the DC motor current and voltage requirements when the air compressor is meeting the design air requirements.

Linear Current Booster

To maximize air pumping at lower sunlight levels throughout the day, a linear current booster is used. Some PV array and air compressor combinations may not need a linear current booster if the current and voltage characteristics of the air compressor motor keeps the PV array operating near its peak power point throughout the day at the varying irradiance levels.

Diffuser and Check Valve

For adequate oxygen transfer, a diffuser discharges bubbles that range in diameter from 1 to 3 mm. The diffuser is made with four air stones on a PVC pipe manifold. It is connected to the air compressor with 3/8" clear reinforced plastic tubing. The tubing is on a reel to adjust the depth of the diffuser to a maximum of 15 feet. The air stones will pass 30 micron dirt particles. If they become clogged with dirt or algae, they may be cleaned with a muriatic acid bath.

To keep water from entering the compressor, a check valve is installed in the air supply tubing connecting the diffuser to the air compressor. A check valve with a maximum pressure drop of 2 psi is used.

Electrical Design

The electrical design must be in strict compliance with the National Electric Code (NEC). Article 690 of NEC specifically addresses safety standards for the installation of PV systems. This water aeration system includes: (1) a disconnect switch to isolate the PV array from the rest of the system, (2) a 10-amp fuse connected between the linear current booster and the compressor motor, (3) U.L.-listed wiring for outdoor use and for exposure to sunlight and water spray, and with sufficient voltage and ampacity ratings, (4) water-proof junction boxes and anti-oxidation coating for electrical contacts, and (5) surge arrestors for lightning protection.

Because batteries for energy storage are not used, protection diodes for the PV array are not required.

Mechanical Design

The aeration system is installed on a float so that it can be easily towed to different locations on a lake. The float is constructed of weatherproof materials and provides for the attachment of 2 anchor lines. The overall size of the aeration system permits transporting in a compact pick-up truck.

The array is secured to the float at a tilt of 5 degrees from the horizontal. This prevents water collection on the module surfaces and maximizes the insolation during the summer months. Metal and electrical component materials for the aerator system are chosen for corrosion resistance in the hot, humid, salt-air climate of Florida. Direct contact between dissimilar metals is avoided. Module frames are at least as corrosion resistant as 6063 aluminum, with an anodized or other permanent coating that provides at least a five-year protection at the site environment. Stainless steel fasteners are used for bolted connections. The DC motor and air compressor are in

a vented enclosure box for protection from water spray.

Completed System

Based on competitive bids, the contract for the portable PV powered water aeration system was awarded. Figure 1 is a picture of the completed system taken before placing the aeration system in the lake. The major components of the aeration system are listed in Table 1.

The two PV modules are bolted to the 1.5" aluminum angle used for the support structure. Marine plywood is used for the floor on which the air compressor with dc motor, the linear current booster, and the air line reel for the diffuser are attached. The diffuser is suspended beneath the float. The depth of suspension is adjustable up to 15 feet. The six plastic flotation drums are secured with stainless steel straps. Marine cleats in each corner permit anchoring or towing. The assembled weight of the aeration system is just 130 pounds.

Fig 1. Portable PV powered water aeration system.

TABLE 1 Aeration System Major Components

Component Description

PV Array Two 60 watt PV modules

Compressor With 12 volt 9 amp dc motor, 1 cfm @ 10 psi

Linear Current Booster Maximum 10 amp continuous output

Structure Aluminum angle and marine plywood

Flotation 6 styrofoam-filled plastic drums

OPERATING EXPERIENCE

The portable aeration system has been in operation for over seven months and Lee County is pleased with its performance. Each day it begins to aerate as soon as the PV modules receive sunlight. No failures or operating difficulties have occurred with any of its components. Because it is portable, it can be easily transported in a small truck and towed with a small boat. Once in the proper location, the diffuser is lowered into the water and the float is anchored in place or tied to restraining posts.

So far, Lee County has used the aeration system for two applications. The first is to aerate the water in a public lake swimming area, and the second is to aerate water in a newly constructed catfish farm exhibit. For both applications, the oxygen content of the water was increased during the day, but at nighttime when the PV-powered aeration system does not operate the oxygen content of the water returned to its original values. Because this is not acceptable for raising fish, the catfish farm operates an additional aeration system at night using electricity from the utility. If batteries were included as a part of the PV-powered aeration system, it could be used for night operation.

The swimming area posed another problem for the portable water aeration system. The float type structure attracted swimmers, some of whom attempted to climb on the structure. Fearing for the safety of the swimmers, the swimming staff relocated the system farther away from the swimmers. For swimming areas, it appears preferable to mount the system on shore and use a long air hose along the lake bottom to place the diffuser in the desired location rather than to use a float.

SUMMARY

A portable PV-powered aeration system is an attractive way to improve the water quality of lakes. As shown by the system operated by Lee County, the appropriate design criteria can produce a reliable system that requires little operator intervention. The portable nature of this system permits the operator to conveniently relocate the system and aerate bodies of water as needed.

Because the Lee County aeration system only operates during the day when the sun shines, the oxygen content of the lake is not improved during the night. For fish farms, and other applications that require aeration at night, the addition of batteries to the PV-powered aeration system for night time operation would be needed.

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