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Preliminary experimental study of a small reverse osmosis wind-powered desalination plant

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Abstract

The paper describes the work carried out in the development of a small wind-powered desalination plant. An alternative control system was studied to serve as a direct interphase between a reverse osmosis desalination plant and a small wind energy conversion system. The main purpose was to reduce or eliminate the need for an energy storage system (usually, a battery bank). In order to achieve this objective, an experimental prototype of a desalination plant and a wind generator simulator were developed. The systems were evaluated under laboratory-controlled conditions and subjected to field trials. The experimental plant desalinates highly saline seawater (35,000 mg/L) at a rate of approximately 0.4 m^3/d. This amount of potable water is sufficient to supply the basic water demands in a small community in an isolated location. The paper also describes the identification of technical problems associated with operating a desalination plant with an intermittent source of energy (wind).

Keywords: Wind energy; Simulation; Reverse osmosis; Seawater desalination

1. Introduction

Reverse osmosis (RO) is a process used to desalinate salt water. The process has the advantage that it requires low energy consumption compared to other desalination processes. Feron and Smulders of Eindhoven Technical University (Netherlands) found in the 1980s that RO has the lowest energy consumption amongst most methods of desalination [1].

In general, desalination processes are required in coastal or isolated locations where there are no water sources other than water from the sea, or the water source are in deep wells that produce salty water. A convenient alternative is the supply of potable water through independent and self-sufficient solutions such as that offered by this combination of technologies (a RO plant and the wind energy conversion system).

Depending upon the concentration of salts dissolved in water, the pressure required for the

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RO process varies from 1.4 to 8.3 MPa (200–1,200 psi). There is a practical relationship that allows the calculation of the minimum required osmotic pressure: at least 7 kPa (1 psi) is required for every 100 mg/L of salts dissolved in the water; therefore, if the seawater has 35,000 mg/L of salts, at least 2.45 MPa (350 psi) are needed for the desalination process to take place [2].

Desalination plants usually run on fossil fuel (diesel or motor gasoline) generators or they are connected to the local electricity network. Sometimes energy is generated by renewable energies (solar or wind) which use energy storage systems (battery banks). The battery bank is expensive in RO plants for this type of application. Consequently, if a control system can be devised to allow the direct operation of the plant, initial costs will fall substantially, and the system will be simpler and more feasible to use.

The RO desalination plant is composed of five systems (Fig. 1): (1) a pre-treatment system, whose function is to reduce substances harmful to the RO membrane; (2) the desalination system, composed of a high-pressure pump and the RO membrane; (3) the power supply system, whose function is to generate the power required, (4) a control system, i.e., the interphase between the power supply and the desalination system; and (5) the post-treatment system to make the water of optimum quality for human consumption.

2. Pretreatment systems

The function of a pre-treatment system is to eliminate agents that will block the membrane. Most of these pretreatment systems are complex, however, and what is needed is a simple and effective form of pre-treatment which requires no electricity for operation (a passive system).

A granular medium slow pre-filter was chosen [3] due to its simplicity in construction, operation and low associated costs. The first two stages of the pre-filter are anthracite (amorphous fragile coal) beds and river sand. They allow suspended colloid particles to filter out by deposition on the grains of the filter medium. The final stage of the pre-filter uses granulated activated coal, which is used to free the filtered water of oxidizer agents and bacteria that might form a biological block.

The results of tests on this type of pre-filter show that it is effective for removing agents harmful to the RO membrane. The design parameters of the pre-filter are determined by the type of medium, size and depth of the filtration beds, the surface area of the filters, the static pressure head available to act as the driving force and the method of operation of the pre-filter including cleaning.

The performance of this type of pre-filter is determined by the head loss through the filter and the resulting quality of the water. The pre-filter should be changed each time the maximum known head loss is reached or each time the quality of the pre-filtered water indicates that this should be done. The change of pre-filter is easy, and it demands no more than removing the blocked-up filtration media and adding new filtration beds [4].

3. Pump–RO membrane system

This system is composed of a commercial RO membrane and a high-pressure pump. The membrane was chosen, bearing in mind, two main constraints: it must be designed to desalinate seawater and it must have the lowest possible feed flow rate. The membrane selected was the SW30-2521 (Dow Chemicals FILMTEC™ Division), with a maximum flow rate of 0.37 L/s and a maximum operating pressure of 6.9 MPa (1,000 psi).

The pump used was a Hydra-Cell M-03-E (Warner Engineering) positive displacement piston pump; its main features are a maximum flow of 0.14 L/s and 8.2 MPa maximum operating pressure. The pump is made of stainless steel (essential for operation in salt water).