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A review of the water desalination systems integrated with renewable energy

Ahmed Alkaisi[a,b,*], Ruth Mossad[b], Ahmad Sharifian-Barforoush[a,b]

[a]*Computational Engineering and Science Research Centre, University of Southern Queensland, Toowoomba, QLD 4350, Australia*
[b]*School of Mechanical and Electrical Engineering, University of Southern Queensland, Toowoomba, QLD 4350, Australia*

Abstract

Water and energy are indispensable entities for any flourishing life and civilization. The water and energy scarcities have emerged due to the dramatic growth in the population, standards of living, and the rapid development of the agricultural and industrial sectors. Desalination seems to be one of the most promising solutions to the water problem; however, it is an intensive energy process. The integration of the renewable energy into water desalination systems has become increasingly attractive due to the growing demand for the water and energy, and the reduction of the contributions to the carbon footprint. The intensive investigations on the conventional desalination systems, especially in the oil-rich countries have somewhat overshadowed the progress and implementation of the renewable energy desalination (RED) systems. The economic performance evaluation of the RED systems and its comparison with conventional systems is not conclusive due to many varying factors related to the level of technology, the source of energy availability, and the government subsidy. The small RED plants have a high capital cost, low efficiency and productivity which make RED systems uncompetitive with the conventional ones. However, the selection of the small RED plants for the remote arid areas with small water demands is viable due to the elimination of the high cost of the water transportation, and the connection to the electricity grid. The purpose of this paper is to review the technology, energy, and cost of the recent available desalination systems and their potential to be integrated with the renewable energy resources. This review suggests that the solar still distillation (SD) system, which is simply a natural evaporation-condensation process, is the most practical renewable desalination technique to be used in the remote arid areas; however, a further research is required to enhance their performance and to increase the productivities of these systems.

* Corresponding author. Tel.: +6-140-267-4227
E-mail address: AhmedKasimTaha.Alkaisi@usq.edu.au

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1. Introduction

In spite of the fact that water covers about 71 percent of the Earth's surface area, however, it is a challenge to meet all humans, animals and plants demand to freshwater. Freshwater is about 2.5% of total water quantity, most of it is as glaciers, ice caps, and groundwater, only 0.008% represents the accessible surface freshwater [1]. Population growth and industrialization have worsened the problem of water shortage. One-third of the world residents currently undergo severe water stress and the percentage is expected to increase [2]. Water scarcity occurs when water supply falls below 1000 cubic meters per person per year [3]. One of the most promising solution to overcome the water shortcoming is desalination. Desalination is defined as, the process of removing dissolved salts and minerals from saline water to produce potable water. Saline water can be classified depending on the Total Dissolved Solids (TDS) for brackish water TDS is up to 10,000 ppm, and for seawater TDS is up to 45,000 ppm [4]. While the permissible limit of salinity in potable water is in the range of (500 to 1000 ppm) [5]. However, desalination is an extensive energy process in which to produce 1000 cubic meters of water per day it requires about 10000 tons of fossil fuel per year [6]. Replacing the depleted fossil fuel by renewable and sustainable energy resources becomes a crucial need to decrease the carbon footprint and greenhouse gases emission which they are the main reasons of global warming and climate change. The purpose of this paper is to review the technology, energy, and cost of the recent available desalination systems and their potential to be integrated with the renewable energy. This review hopes to help decision makers to compare the available options and researchers to select the appropriate desalination process for further investigations and developments.

2. Desalination systems

Desalination systems can be classified according to the energy source such as; thermal, mechanical, electrical and chemical energy sources. Another classification depends on the desalination process: evaporation-condensation, filtration, and crystallisation technique. Some of the desalination technologies are still under development such as; solar chimney, greenhouse, natural vacuum, adsorption desalination, membrane distillation (MD), membrane bio-reactor (MBR), forward osmosis (FO), and ion exchange resin (IXR). The reverse osmosis (RO) followed by multi-stage flashing (MSF) and multi-effects distillation (MED) systems are the most worldwide implemented desalination technologies. Figure 1(a) illustrates the main desalination techniques around the world. According to the International Desalination Association (IDA) 2015, more than 300 million persons depend on water produced by 18426 desalination plants in 150 countries, which are providing more than 86.8 million cubic meters per day [7]. The western and developed countries prefer RO systems due to its efficient power consumption, while the Middle East and Gulf countries prefer MSF and MED systems due to the abundant source of available oil. The largest desalination plant which started to operate at the end of 2014 is Ras Al-Khair in Saudi Arabia. This plant produces about 728,000 cubic meters of desalinated water per day by implementing both the MSF and RO technologies [8]. The second largest desalination plant is Carlsbad in California, USA which produces about 190,000 cubic meters of desalinated water per day by implementing RO technology, opened in December 2015 [9]. The simplest desalination technology is the solar still distillation (SD) system, which is suitable to the remote areas with a small water demand due to the low productivity of these systems. Figure 1(b) presents the recent global contribution of each desalination technology [10, 11]. Table 1 shows the advantages and disadvantages of some well-known commercial desalination technologies [12].