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Performance evaluation of the "large SMADES" autonomous desalination solar-driven membrane distillation plant in Aqaba, Jordan

Fawzi Banat[a*], Nesreen Jwaied[a], Matthias Rommel[b], Joachim Koschikowski[b], Marcel Wieghaus[b]

[a]*Department of Chemical Engineering, Jordan University of Science and Technology, PO Box 3030, Irbid, Jordan Tel. +962 (2) 720-1000; Fax: +962 (2) 720-1073; email: banatf@just.edu.jo*

[b]*Fraunhofer Institute for Solar Energy Systems ISE, Heidenhofstr. 2, 79110 Freiburg, Germany*

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Abstract

In search of new sources of water supply, seawater desalination is increasingly recognized as a viable option. In arid coastal areas, the lack of fresh water coincides often with an abundance of solar energy. Coupling desalination systems with renewable energy technologies is of great importance. Project SMADES funded by the EC has sponsored the development of a so-called "large SMADES" system. The system is designed to provide high quality potable water in remote coastal areas with low infrastructure and without connection to a grid. The energy for the desalination process is supplied entirely by solar thermal collectors in the form of heat on a temperature level of 60°C to 80°C. The desalination units are improved membrane distillation (MD) modules with internal heat recovery function. The electrical auxiliary energy which is required to drive the pumps and valves for the automatically operated systems is supplied by PV panels. The collector area is 72 m², the hydraulic loop of the collector field comprises a solar heat storage tank of 3 m³ and the collector loop is separated from the seawater loop of the MD-desalination-modules. Automatic controls start up the desalination unit whenever sufficient sunlight is present to provide hot water and electricity for pumping from the solar collectors and PV panels. This paper describes this plant that has been assembled at the Marine Science Station (MSS) of Aqaba, Jordan, and presents the results of the first few months of operation. The feed water was seawater directly from the Red Sea.

Keywords: Small-scale; Remote communities; Solar desalination; Membrane distillation; Performance ratio

*Corresponding author.

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1. Introduction

Communities in arid coastal areas, especially island communities, are experiencing shortages of potable water. Many of these communities are small and remote. Seawater desalination is an alternative that seems feasible to solve part of the chronic water supply problems. Nonetheless desalination consumes a large amount of energy. The continually increasing prices of crude oil will cause the operating costs of desalination to increase significantly. Countries in the Middle East suffering from severe water shortages, such as Jordan, cannot afford the energy required for desalination. Fortunately, these countries are blessed with high solar insolation. Therefore, solar desalination can be a suitable alternative to cope with water scarcity and overcome water deficit. Efficient technologies are developed to utilize the solar energy. Solar energy can be used directly to produce fresh water in solar stills or indirectly where thermal or electrical energy from a solar energy system is provided to a desalination unit.

Jordan, whose water deficit currently stands at 500 million cubic meters per year, did not considered desalination seriously 20 years ago because of the high cost of desalination technologies at the time. Desalination is now a well-established technology and available at lower cost than before. Desalination of water from the Red Sea/Aqaba Gulf might be economically feasible by efficient use of non-conventional energy resources. In Jordan, the average insolation intensity on a horizontal surface is approximately 5–7 kWh/m^2/d, which is one of the highest in the world [1]. This has brought up desalination as a viable alternative for Jordan.

Apart from cost considerations solar desalination has a positive impact on a large number of health and environmental problems. The use of renewable energy not only lessens, or even eliminates the unsustainable consumption of fossil fuels, but also the pollutants they produce. In recent years, the research community has worked intensively on coupling desalination systems with renewable energy technologies. Many pilot plants have been built and operated with encouraging results.

Membrane distillation combines the use of both distillation and membrane technology. In this process saline water is heated to raise its vapor pressure and this vapor passes through hydrophobic membrane pores that allow vapor to pass but not liquid water. The passing vapor is then condensed on a cooler surface to produce fresh water. The main advantages of membrane distillation are in its simplicity, and the requirement for only small temperature differentials to operate the process. Like any distillation process, its energy requirement and product water quality are independent of feed water quality. Because it operates at low temperatures (50–90°C), the feed water can be heated by solar-thermal collectors. The primary energy requirement is thermal, although some electrical energy is required to pump the water through the system.

A number of efforts have been made to develop and improve the performance of desalination by solar-driven membrane distillation processes [2–6]. In one of the most recent publications Ding et al. [7] concluded that heat recovery from permeate to the feed is the only way to improve the energy efficiency of solar driven membrane distillation processes. The use of latent heat of condensation to preheat the feed water has shown good improvement in the process performance.

Under the umbrella of project SMADES, stand-alone solar-driven membrane distillation systems were developed to generate a stable supply of water to consumers in remote areas far away from the public grid. First, so-called "compact SMADES" systems were designed and tested in different countries (Jordan, Morocco, and Egypt) to generate process parameters and design data needed for designing the so-called "large SMADES" systems. Results from the