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A small PV-driven reverse osmosis desalination plant on the island of Gran Canaria

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Abstract

A reverse osmosis (RO) plant with an average daily drinking water production of 0.8–3 m^3/d was installed by the Aachen University of Applied Sciences and the Energy and Water Research Centre of the Canary Islands Technological Institute (CIEA–ITC) at the test fields of the Spanish institute in Pozo Izquierdo (Gran Canaria Island). The plant is supplied by a stand-alone 4.8 kWp photovoltaic (PV) system with an additional battery storage of 60 kWh. The installation constitutes the smallest PV-supplied seawater desalination plant currently in operation. On behalf of this prototype, the feasibility of small PV–RO systems (1–5 m^3/d) is being investigated. The technical details of the RO plant and the energy supply are presented briefly and the operation strategies of the system are presented. Three different regulation strategies for the energy management of the plant are compared and recommendations for an optimized operation are given.

Keywords: Reverse osmosis; Photovoltaic; Decentral water production; Energy management; Operation strategies

1. Introduction

Reverse osmosis (RO) supplied by photovoltaic (PV–RO) is a promising solution for small-scale desalination. Mohsen and Al-Jayyousi [1] investigated the feasibility of different desalination technologies to cover the increasing water demand in Jordan. They carried out an AHP multi-criteria analysis considering economic, technical and environmental criteria, and compared the five most important desalination technologies:

- Multi-effect desalination (MED)
- Reverse osmosis (RO)
- Vapor compression (VC)
- Electrodialysis (ED
- Multi-stage flash (MSF)

for the production of drinking water from brackish and seawater. They pointed out that the

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RO technology with its advantages of the suitability for both sea and brackish water and its low power requirements compared to MED and VC is well suited for Jordan and other comparable regions in the world. RO ranked first of the five desalination technologies. Furthermore, RO is very flexible in water quantity and quality, site location and start-up and shut-down.

In countries without fossil fuel resources and in remote areas, solar energy supplies can be economical in many cases for stand-alone applications compared with fossil-driven small-scale desalination plants, which are relatively expensive to operate in remote areas. Houcine et al. [2] pointed out the importance of small-scale desalination technologies driven by renewable energies for the provision of potable water to remote and isolated communities where the electric grid and the proper infrastructure are lacking. Beside the VC technology, RO plants have a modular construction and can be well coupled to a solar photovoltaic, wind (electric as well as mechanical coupling) and an electric geothermal energy supply.

To investigate the technical feasibility and economic viability of PV–RO systems, a small demonstration plant has been constructed and installed at the test field of the Energy and Water Research Centre of the Canary Islands Technological Institute (CIEA–ITC) in Pozo Izquierdo, on the island of Gran Canaria. It serves for experimental tests for an energy-efficient autonomous operation of RO plants. Different control and regulation strategies to increase the daily water production and to lower the investment costs will be investigated.

2. Technical installations

2.1. Reverse osmosis plant

The central unit of the plant consists of a spiral-wound seawater membrane (Filmtec HR3040) for a maximum potable water production of 3 m^3/d. Due to the seawater supply by a nearby beach well, two cartridge filters are sufficient for the pre-treatment of the feed water. A 60 l permeate water tank was installed for the flushing of the membrane, the water counters and all seawater pipes of the plant after plant shut-down. Two different flushing methods will be investigated in the near future: flushing by gravity and mechanical flushing by pumping.

The plant is equipped with motorized valves for an automatic start-up and shut-down with built-in conductivity meters (permeate and brine), temperature and pH sensors for the control of the permeate quality. Alarm controls for these parameters as well as for the feed pressure and pressure drop at the membrane automatically monitor plant operation and enable a secure plant operation with guaranteed permeate water quality. The technical details of the RO installations were previously published [3].

2.2. Renewable energy supply

The energy supply of the RO plant is realized by a stand-alone photovoltaic generator. This is a suitable solution for small electric loads, which have to be supplied far away from the electric grid. This will be the situation in regions where a supply with relatively small quantities of good quality drinking water is of special interest (e.g., drinking water for small communities, hospitals).

The water needs shall be met with high reliability in the summer months and with lower reliability in the winter months. (Rainfall could compensate possible deficits in the water supply in wintertime). Measured solar radiation data from the Pozo Izquierdo site (latitude 28°N) have been used as the basic criteria for system design. The yearly average of the daily solar irradiation on a horizontal surface at the site is 5.6 kWh/m^2. This value is representative for semi-arid areas (e.g., West African coast and Near East at this latitude range).