

Using Solar Energy to Drive a Reverse Osmosis Plant for Seawater Desalination in Sudan

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Abstract

In recent decades, water shortages have become a significant problem. Sudan is no exception. In addition to the main towns of Port Sudan and Suakin, many villages scattered along the Red Sea coast also experience severe shortages of fresh water and electricity supply. The problem recently worsened after the Arbaat Dam's collapse, which was Port Sudan's main source of fresh water. Desalination of seawater and brackish water can play a significant role in addressing this issue. In this field, reverse osmosis (RO) is predominant due to its many advantages. However, this technology consumes a significant amount of energy. In many places around the world, freshwater shortages are accompanied by an abundance of solar energy. In this study, one of the existing desalination plants in Port Sudan was considered to investigate the possibility of shifting it to run on solar power instead of electricity from the national grid, or that generated by diesel engines. The plant under study is a small RO unit with a capacity of 7 m³/h. It consumes energy at a rate of 6.6 kWh/m³. PVsyst software has been used to design and simulate the solar photovoltaic system which can drive the desalination unit. Results showed that with a PV array total power of 95.2 kW_p and 9360 Ah battery capacity, the system can work steadily for 7 hours daily to produce 49 m³/day of fresh water. The solar system's annual performance ratio (PR) is 60.3% with a solar fraction equal to 100%. While the simple payback period (SPB) for the photovoltaic system is found to be 1.74 years.

Index Terms—Solar desalination, Desalination, Rural areas, PV-RO, Freshwater, PV system.

I. INTRODUCTION

WATER is the basis of living things; the oceans cover 71% of the Earth's surface and contain 97% of the total water. About 97.3% of water on Earth is not suitable for direct use because it is salt water, represented in seas, and oceans. The rest (2.7%) is only freshwater. [1]. In the last few decades, water shortage problems have emerged, especially in developing countries. The socio-economic conditions associated with water use have also changed dramatically due to the continuous development of the population's livelihood, the introduction of large-scale irrigation, and the development of industry [2]. Under the current circumstances, it is estimated that by 2050 about 40% of the world's population will suffer a water shortage [3]. To fill this deficiency, it is necessary to resort to desalination of salt water from groundwater and seawater. [4] [5].

A) Water Desalination

Desalination is a general term for removing dissolved solids and producing fresh water from raw water such as seawater, brackish water, and inland water. Recycled water reclamation increasingly describes a group of processes used to reduce the number of solutes (solids in water). Fresh water is defined as having less than 1,000 mg/L of salts or total dissolved solids (TDS) [6].

More benefits are being paid to desalinating seawater and brackish water to save fresh water. Three methods are most common for desalination, reverse osmosis (RO), multi-stage flash (MSF), and multi-effect distillation (MED) [7]. Nearly 69% of global installed capacity are RO plants [5] [8]. Reverse osmosis technology is predominant due to some advantages. It can be designed in a wide range of capacities, can handle a wide range of raw water salinity, has shorter maintenance shutdown times, and its lower specific energy consumption compared with MSF and MED plants [9]. The suitability of desalination techniques depends on several criteria including the feed water quality level, energy source, removal efficiency, energy requirements, etc. However, all technologies used for water desalination have in common that they require a large amount of thermal or electrical energy. [10] [11].

From an economic and environmental view, producing 1,000 tons of fresh water per day requires burning 10,000 tons of fossil fuels during the year [6]. Accordingly, the emission of CO₂ from seawater RO plants ranges from 1.7 to 2.8 kg of CO₂ for 1m³ of fresh water. For MED plants this value ranges from 7.0 to 17.6 kg CO₂/m³, and 15.6 to 25 kg CO₂/m³ for MSF desalination plants [12]. Globally, the cost of freshwater produced by RO is around 0.5 US\$/m³, and it is estimated as 0.7 US\$/m³ for MED plants,

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