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On the use of wind energy to power reverse osmosis desalination plant: A case study from Ténès (Algeria)

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ABSTRACT

The aim of this study was to provide a detailed analysis of wind energy resources for seawater reverse osmosis desalination (SWRO), in a case study region of Ténès Algeria, by using commercial Wasp software. An economic analysis of the environmental benefits was also done using RETScreen software to give details about financial investment hazards and CO_2 emissions reduction. An energy yield and economical analysis was performed of a hypothetical wind farm consisting of 5 wind turbines of type Bonus 2 MW. It was found that wind energy can successfully power a SWRO desalination plant in the case study region.

Contents

1. Introduction

The economic and industrial potentials of renewable energies, such as geothermal, solar and wind, as well as the environmental advantages have been pointed out in several recent studies [1–5]. The first use of geothermal energy, for example, for electric power production occurred in Italy a century ago with the commissioning of a commercial power plant (250 kWe). Small decentralised water treatment plants can also be connected to a wind energy conver-

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tor system. The wind turbines as well as the desalination system can be connected to a grid system [6]. The Kwinana Desalination Plant, for example, located south of Perth in Western Australia, produces nearly 140 ML of drinking water per day, supplying the Perth metropolitan area [7]. Electricity for the plant is generated by the 80 MW Emu Downs Wind Farm located in the state's Midwest region. Alternative energy sources such as nuclear also need to be considered [8]. The Shevchenko BN350 nuclear fast reactor and desalination plant, for instance, situated on the shore of the Caspian Sea, in Kazakhstan, during its lifetime of some 27 years could generate 135 MWe of electric power and provide steam for an associated desalination plant which produced 80,000 m^3/day of potable water [9].

With the world's fresh water demands increasing, much research has been directed at addressing the challenges in using renewable (and environmentally friendly) energy to meet the power needs for desalination plants. Lack of water, for instance, has caused great distress among the population in large parts of the MENA countries (Middle East and North Africa). Renewable energy technologies such as wind, solar, and geothermal and even alternatives such as nuclear show great promise for water [1,8–11]. They fall into two categories; the first includes distillation processes driven by heat produced directly by the renewable energy system (RES), while the second includes membrane and distillation processes driven by electricity or mechanical energy produced by the RES.

The coupling of renewable energies such as wind, solar and geothermal with desalination systems holds great promise for water scarce regions [2,12–14]. Solar energy can also be converted to thermal or electrical (i.e., photovoltaic) energy and then used in water desalination directly or indirectly, respectively [2,12,13]. It can be argued that an effective integration of these technologies will allow countries to address water shortage problems with a domestic energy source that does not produce air pollution or contribute to the global problem of climate change. Furthermore this approach will help to bypass the problems of rising fuel prices and decreasing fossil fuel supplies. Bourouni et al. [15–17] reported on installations using humidification dehumidification processes in the form of evaporators and condensers made of polypropylene and operated at a temperature between 60 and 90 °C. Recently, many medium and large scale water treatment and desalination plants have been partially powered with renewable energy mainly wind turbines, PV cells or both. The energy demand of, for example, the Sureste seawater reverse osmosis (SWRO) plant located in Gran Canaria, Canary Islands, of a capacity of 25,000 m^3/d is provided by a combination of PV cells (rooftop) and the rest from the grid which consist of an energy mix including wind energy [18,19].

2. Water crisis and desalination in the case study country

Algeria has an area of 2,381,741 km^2 and a population of about 33 millions. It is the Africa's second-largest country and the eleventh in the word in term of land area. The country is divided into four main physical regions. The first region located in the north is the Mediterranean coastline of 1200 km in length, where most of the country's population (80%) and industry are concentrated. The second region is the Tell which extends 80–190 km inland from the coast. The next region, lying to the south and southwest is the High Plateau; a highland region of level ground together with the mountains and massifs of the Saharan Atlas of the south region. The fourth region, comprising more than 80% of the country's total area, is the great expanse of the Algerian Sahara [20].

Desalination has become an imperative and inevitable solution for Algeria to overcome its current shortage of potable water. Having exploited seawater desalination largely for industrial use since the sixties, Algeria is now in a hurry to exploit this technology to quench the thirst of its citizens. The total production capacity of the operating plants in Algeria is 661,920 m^3/day. About 47% of it is produced by multistage flash (MSF) and multiple-effect distillation (MED), 44% by reverse osmosis (RO), 5.5% by vapor compression (VC) and 3% by electro-dialysis (ED). More than 67% of the total desalinated water is produced from seawater, 22% from brackish water, 8% from river water and the rest from other sources. The major user of the desalinated water is municipalities with about 49% followed by industries with 45%. The rest is by power, tourist places, military and other sectors.

The Ministry of Water Resources, through Algerienne des Eaux (ADE) and Algerian Energy Company (AEC), started recently the construction of many large-scale seawater reverse osmosis desalination plants. Among these, Hamma (Algiers), Beni-Saf, Mostaganem, Sidna Ouchaa and Honaine in Tlemcen, Cap Blanc and Ténès will supply 200,000 m^3/day each and Skikda, Douaouda, Cap Djenet will supply 100,000 m^3/day each. In order to carry out the large-scale desalination plants installed and under construction, the government approved the proposals according to BOO formula (Built, Own, and Operate) except the MSF plant constructed in the industrial zone of Arzew is in BOT (Built, Own, and Transfer) formula. This procedure will avoid risk of operation and maintenance problems due to lack of skilled manpower for the life of the plants which are estimated to be 25 years [20].

Ténès reverse osmosis desalination plant is located at 3 km from the town centre, with a capacity of 5000 m^3/d, it provides fresh water for some 40 thousands inhabitants. It was receipted on 2006. The plant consumes in average 7.27 GWh/year.

3. Wind power and desalination

Wind is generated by atmospheric pressure differences, driven by solar power. Of the total 173,000 TW of solar power reaching the earth, about 1200 TW (0.7%) is used to drive the atmospheric pressure system [21]. This power generates a kinetic energy reservoir of 750 EJ with a turnover time of 7.4 days. This conversion process mainly takes place in the upper layers of the atmosphere, at around 12 km height (where the 'jet streams' occur). If it is assumed that about 1% of the kinetic power is available in the lowest strata of the atmosphere, the world wind potential is of the order of 10 TW, which is more than sufficient to supply the world's current electricity requirements.

Kalogirou [22] argued that the world's wind energy could supply an amount of electrical energy equal to the present world electricity demand.

Different approaches for wind desalination systems are possible. First, both the wind turbines as well as the desalination system are connected to a grid system. In this case, the optimal sizes of the wind turbine system and the desalination system as well as avoided fuel costs are of interest. The second option is based on a more or less direct coupling of the wind turbine(s) and the desalination system. In this case, the desalination system is affected by power variations and interruptions caused by the power source (wind). These power variations, however, have an adverse effect on the performance and component life of certain desalination equipment. Hence, back-up systems, such as batteries, diesel generators, or flywheels might be integrated into the system.

Small decentralised water treatment plants combined with an autonomous wind energy convertor system (WECs) show great potential for transforming sea water or brackish water into pure drinking water [23]. Also, remote areas with potential wind energy resources such as islands can employ wind energy systems to power seawater desalination for fresh water production. The advantage of such systems is a reduced water production cost com-