Journal of Fundamentals of Renewable Energy and Applications

Karavas and Papadakis, J Fundam Renewable Energy Appl 2017, 7:3
DOI: 10.4172/2090-4541.1000e115

Editorial OMICS International

Renewable Energy Driven Small-Scale Sea Water Reverse Osmosis Desalination Systems: A Survey

Christos Spyridon Karavas and George Papadakis*

Department of Natural Resources and Agricultural Engineering, Agricultural University of Athens, Greece

***Corresponding author:** George Papadakis, Professor of Renewable Energy Technologies, Department of Natural Resources and Agricultural Engineering, Agricultural University of Athens, Iera Odos street 75, Athens 11855, Greece, Tel: 30 210 5294209; E-mail: gpap@aua.gr

Received date: May 17, 2017; **Accepted date:** May 22, 2017; **Published date:** May 24, 2017

Editorial

In recent years, water and energy constitute two of the most important concerns of the worldwide agenda. These resources comprise essential commodities for the preservation of life on Earth and the human survival. At the dawn of the 21st century, there are more than 2 billion people without access to fresh water [1]. Taking into consideration that 97% of the earth's water comes from the oceans, an attractive solution to the lack of potable water is seawater desalination [2]. The main desalination processes are the thermal and the membranes ones. The membrane processes, such as electrodialysis and primarily reverse osmosis (RO), have been implemented not only on desalination but generally on water treatment and now have more global acceptance than thermal processes [3]. RO is a process where the feed water enters a semi-permeable membrane under pressure, larger than the osmotic pressure, and the membrane produces fresh water and concentrate solution [4].

Water separation processes such as desalination require energy to produce fresh water and the minimum theoretical energy for desalination is 1.06 kWh/m^3 [5]. However, desalination plants consume higher amounts of energy per unit volume of fresh water produced. The continuous increase of the fossil fuels prices and their environmental impact as compared to the advantages of renewable energy and corresponding renewable energy systems (RES), makes the combination of RES with desalination units a sustainable and economically viable solution [6]. There are numerous studies for desalination plants powered by renewable energy technologies such as RO desalination units using solar energy, wind energy and thermal energy. Most of them focus on the quantity of the water production from the desalination unit with the aim to minimize the specific energy consumption (kWh/m^3) and the total investment cost.

The Renewable Energy Systems Group (RES Group) at the Agricultural University of Athens (AUA), (www.renewables.aua.gr), focuses on three major issues to SWRO desalination technology powered by RES.

1. Investigation of small-scale SWRO desalination units under full and variable load operation.
2. Autonomous small-scale SWRO desalination systems.
3. Energy Management Systems (EMS) utilizing computational intelligence approaches for SWRO desalination systems.

Research on Stand-Alone SWRO Desalination Plants

In the past two decades, various SWRO desalination systems were developed in many areas in the world such as islands and regions, which face significant shortage in drinking water supply. Most of them use energy recovery devices (such as pressure exchangers and turbine systems) in order to reduce the energy requirements of the RO plant since more than 90% of the input energy to a RO desalination system is wasted in the brine line. Excellent results have been attained with regard to the specific energy consumption when small-scale SWRO desalination units are combined with energy recovery devices [7]. Specifically, a small-scale SWRO desalination unit with energy recovery device can present more than 80% reduction in its energy consumption compared to a same conventional desalination system (without energy recovery device) [8]. Historically, SWRO desalination systems were designed and developed for steady power input (nominal load operation). However, various studies have shown that lower specific energy consumption can be reached when a SWRO desalination unit operates at variable load conditions (over a range of input pressure to the membranes) by keeping constant the energy recovery ratio [9]. A comparative analysis have been experimentally investigated between two SWRO desalination units equipped with different energy recovery devices (hydraulic one and a rotary piston pump) and the results showed that the specific energy consumption presented a reduction of about 16% for both desalination units when operated in variable load conditions [10].

Coupling RES with desalination units leads to environmental benefits and constitute an important factor to the economic and social development of remote areas [11]. Several research and demonstration studies have been carried out about the implementation of RES, such as solar energy through photovoltaics (PV) [12] and solar thermal energy through solar collectors [13-15], in small-scale SWRO desalination plants. Recently, a directly PV driven stand-alone SWRO desalination system (i.e., without the use of any conventional energy storage system) was experimentally investigated under variable load operating conditions and its unit cost of water produced was compared to the cost of transported water in one typical island of the Cyclades complex, Greece. The results showed that the SWRO desalination system led to a considerably lower cost of the produced fresh water and the total monetary gain was more than 60% [16]. This system exploited most of the available PV energy production potential and only a small portion of PV energy was not utilized. This small portion of non-exploitable PV energy comprises of the PV produced energy that is not sufficient to operate the desalination unit (minimum required energy) as well as the energy that could be produced but it is not consumed because the desalination unit operates at nominal load. In other words, it was found that the incorporation of conventional battery storage is not justified for operating the RO unit during daytime. However, in order to take advantage of all the produced energy by PVs and ensure a continuous SWRO system operation during daytime without sharp variations due to the variable PV power generation, short-term energy storage systems can be used [17].

Citation: Karavas CS, Papadakis G (2017) Renewable Energy Driven Small-Scale Sea Water Reverse Osmosis Desalination Systems: A Survey. J Fundam Renewable Energy Appl 7: e115. doi:10.4172/2090-4541.1000e115

Research on Autonomous Microgrids and SWRO Desalination Plants

The integration of new desalination plants and the variable energy production of RES require a cost effective planning strategy in order to design the optimum energy supply system. Except of stand-alone desalination systems, another energy supply system for desalination systems can be the autonomous microgrids [18]. Microgrids are usually small-scale integrated systems and mostly employed in remote or isolated communities [19]. Microgrids enable distributed generation and can cover important needs in the area that they serve namely potable water and electricity [20]. The proper operation of a microgrid requires advanced energy managements systems (EMS) in order to manage and operate the SWRO desalination system, satisfy the water and electrical demand, secure microgrid's economical operation and keep the energy interchange between production and consumption stable. Several EMS have been developed based on computational intelligence techniques such as fuzzy logic [21] and fuzzy cognitive maps [22,23].

The RES Group has focused its efforts on developing Decentralized EMS (DEMS) based on multi-agent systems (MAS). MAS emerge as a solution to decentralized coordination problems as the coordination between the agents is succeeded in the absence of a central controller. A Multi-agent DEMS (MAS-DEMS) can optimize the electricity supply to desalination plants and can operate the desalination plant under variable and intermittent conditions. A MAS-DEMS was compared with a centralized EMS (CEMS) for an AC polygeneration microgrid and the results showed that the MAS-DEMS can perform satisfactorily and resulted in lower net present cost than the CEMS [24]. Recently, the RES Group designed, built and experimentally investigated of a DC microgrid, which incorporates short-term energy storage systems, in order to electrify a small-scale SWRO desalination unit. A MAS-DEMS was implemented in the DC microgrid to ensure the optimum microgrid's operation. Furthermore, the agents communicate and cooperate with each other in order to take decisions about the energy production and the energy storage. The agents also decide about the fresh water production by determining the operation point of the desalination unit with the use of computational intelligent technique (Fuzzy Cognitive Maps). A schematic diagram of AC and DC microgrid incorporating SWRO desalination unit is presented in Figure 1.

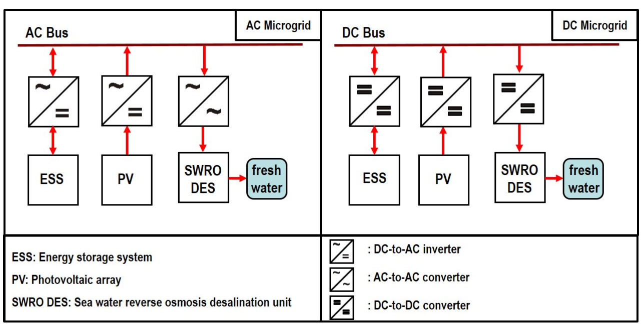

Figure 1: AC and DC microgrid incorporating small-scale SWRO desalination unit.

Acknowledgement

This work was conducted within the framework of the research project "Development of Energy Management Systems for the Design and Control of Autonomous Hybrid Systems and Microgrids, incorporating Computational Intelligence Techniques", funded by the Scholarship Foundation of Greece in the context of "RESEARCH PROJECTS FOR EXCELLENCE IKY / SIEMENS".

References

1. Gosling SN, Arnell NW (2016) A global assessment of the impact of climate change on water scarcity. Climatic Change 134: 371-385.
2. Fritzmann C, Löwenberg J, Wintgens T, Melin T (2007) State-of-the-art reverse osmosis desalination. Desalination 216: 1-76.
3. Lee KP, Arnot TC, Mattia D (2011) A review of reverse osmosis membrane materials for desalination-development to date and future potential. J Membrane Sci 370: 1-22.
4. Greenlee LF, Lawler DF, Freeman BD, Marrot B, Moulin P (2009) Reverse osmosis desalination: water sources, technology, and today's challenges. Water Res 43: 2317-2348.
5. Elimelech M, Phillip WA (2011) The future of seawater desalination: energy, technology, and the environment. Sci 333: 712-717.
6. Ghaffour N, Lattemann S, Missimer T, Ng KC, Sinha S, et al. (2014) Renewable energy-driven innovative energy-efficient desalination technologies. Appl Energy 136: 1155-1165.
7. Mohamed ES, Papadakis G, Mathioulakis E, Belessiotis V (2005) The effect of hydraulic energy recovery in a small sea water reverse osmosis desalination system. Exp Econ Evaluat Desalination 184: 241-246.
8. Mohamed ES, Papadakis G, Mathioulakis E, Belessiotis V (2006) An experimental comparative study of the technical and economic performance of a small reverse osmosis desalination system equipped with an hydraulic energy recovery unit. Desalination 194: 239-250.
9. Dimitriou E, Mohamed ES, Kyriakarakos G, Papadakis G (2014) Experimental investigation of the performance of a reverse osmosis desalination unit under full and part load operation. Desalination Water Treat 53: 3170-3178.
10. Dimitriou E, Mohamed ES, Karavas C, Papadakis G (2014) Experimental comparison of the performance of two reverse osmosis desalination units equipped with different energy recovery devices. Desalination Water Treat 55: 3019-3026.
11. Gude VG, Nirmalakhandan N, Deng S (2010) Renewable and sustainable approaches for desalination. Renew Sustain Energy Rev 14: 2641-2654.
12. Mohamed ES, Papadakis G, Mathioulakis E, Belessiotis V (2008) A direct coupled photovoltaic seawater reverse osmosis desalination system toward battery based systems - a technical and economical experimental comparative study. Desalination 221: 17-22.
13. Kosmadakis G, Manolakos D, Kyritsis S, Papadakis G (2010) Design of a two stage Organic Rankine Cycle system for reverse osmosis desalination supplied from a steady thermal source. Desalination 250: 323-328.
14. Kosmadakis G, Manolakos D, Papadakis G (2010) Parametric theoretical study of a two-stage solar organic Rankine cycle for RO desalination. Renew Energy 35: 989-996.
15. Kosmadakis G, Landelle A, Lazova M, Manolakos D, Kaya A, et al. (2016) Experimental testing of a low-temperature organic Rankine cycle (ORC) engine coupled with concentrating PV/thermal collectors: Laboratory and field tests. Energy 117: 222-236.
16. Karavas CS, Arvanitis KG, Mohamed ES, Dimitriou E, Papadakis G (2017) Direct driven small scale sea water reverse osmosis desalination unit powered by PV: Case study of an Aegean Sea Island, Greece.
17. Kyriakarakos G, Piromalis DD, Arvanitis KG, Dounis AI, Papadakis G (2015) On battery-less autonomous polygeneration microgrids: Investigation of the combined hybrid capacitors/hydrogen alternative. Energy Convers Manage 91: 405-415.

18. Lienhard JH, Thiel GP, Warsinger DM, Banchik LD (2016) Low carbon desalination: status and research, development, and demonstration needs. Report of a Workshop Conducted at the Massachusetts Institute of Technology in Association with the Global Clean Water Desalination Alliance.
19. Hatziargyriou N, Asano H, Iravani R, Marnay C (2007) Microgrids. IEEE Power and Energy Magazine 5: 78-94.
20. Kyriakarakos G, Dounis AI, Rozakis S, Arvanitis KG, Papadakis G (2011) Polygeneration microgrids: A viable solution in remote areas for supplying power, potable water and hydrogen as transportation fuel. Appl Energy 88: 4517-4526.
21. Kyriakarakos G, Dounis AI, Arvanitis KG, Papadakis G (2012) A fuzzy logic energy management system for polygeneration microgrids. Renew Energy 41: 315-327.
22. Kyriakarakos G, Dounis AI, Arvanitis KG, Papadakis G (2012) A fuzzy cognitive maps–petri nets energy management system for autonomous polygeneration microgrids. Appl Soft Comput 12: 3785-3797.
23. Kyriakarakos G, Dounis AI, Arvanitis KG, Papadakis G (2017) Design of a Fuzzy Cognitive Maps variable-load energy management system for autonomous PV-reverse osmosis desalination systems: A simulation survey. Appl Energy 187: 575-584.
24. Karavas CS, Kyriakarakos G, Arvanitis KG, Papadakis G (2015) A multi-agent decentralized energy management system based on distributed intelligence for the design and control of autonomous polygeneration microgrids. Energy Convers Manage 103: 166-179.