Feasibility Study of Hybrid Renewable and Waste Heat Energy Driven Seawater Desalination

Proposed By

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Research Title

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Introduction

Energy is an essential component of both economical growth and socio-economic development. Renewable energy provides a variety of environmentally friendly solutions as well as future energy security. The integration of renewable energy technologies for water desalination is increasing day by day. This is also justified by the fact that the areas where there is shortage of drinking water are having huge amount of solar energy resources. Same is the case of Ras Al Khaimya (RAK) of United Arab Emeritus (UAE). Though, initial cost is bit higher, in the long term perspectives these solar energy based technologies are feasible because of its simplicity. A very brief review to this effect reveals that an optimum technical and economic design and evaluation of the technology is necessary so that it can be implemented in hot, dry and remote regions. The techno-economic performances of these technologies prefers Reverse Osmosis (RO) based desalination as the technology of choice with continued advances being made to reduce the total energy consumption and lower the cost of water produced (M. Eltawil et al, 2009) . However, Membrane Distillation (MD) seems to be a promising innovative alternative to the RO because the MD technology can utilize low grade heat contrary to electricity that is a must in RO process. Furthermore, its simple and reduced maintenance requirement may lead a robust operation which consequently make it less sensitive to process fluctuations (A. Martin,

2007). The proposed research will review the available technologies for seawater desalination in terms of both possibility of integration with solar energy technologies and low grade waste energy. The research is supposed to deliver an optimum design for sea water desalination from both innovation and techno-economic feasible perspective.

Objective

The main objective of the proposed project is to review the technological advancement of the various state-of-art hybrid desalination systems powered by solar thermal and/or waste heat, design of an innovative solar thermal and/or hybrid waste heat powered small to medium scale desalination prototype plant applicable to the UAE climatic conditions so that it could be highly efficient and cost effective system for seawater desalination. As other technologies like MED and MEF and RO are at the final stage of technological maturity with full commercialization having very little space for innovation and development, the focus of the study will be given to emerging multi-stage MD concept that has to be tested and verified on real conditions. The research outcome can be used for setting up prototype experimental test facility in RAK- UAE for further investigation and validation of the performance. Technical simplicity, economical viability, long maintenance-free operation periods and high-quality fresh water output will also be the most important aims of the research.

Specific objectives

i) Technological review of desalination technologies
ii) Design of hybrid solar desalination unit with MD concept with possibility of using waste heat in UAE-RAK climatic condition
iii) Documentation of the study so that it can be up scaled for the prototype development and experiment validation

Literature Review

The use of solar energy in thermal desalination processes is one of the most promising applications of the renewable energies. Solar desalination can either be direct; use solar

energy to produce distillate directly in the solar collector, or indirect; combining conventional desalination techniques, such as multistage flash desalination (MSF), vapor compression (VC), reverse osmosis (RO), membrane distillation (MD) and electrodialysis, with solar collectors for heat generation (H. Qiblawey et al, 2008). Direct solar desalination compared with the indirect technologies requires large land areas and has a relatively low productivity, however, it is cost competitive to indirect system for small-scale production (H. Qiblawey et al, 2008).

Membrane distillation (MD) is a technique which is operated with thermal energy but also uses a membrane for the separation of pure water from the concentrated solution. With regard to the implementation in solar driven stand-alone desalination system it holds important advantages. Fraunhofer ISE develops solar thermally driven compact desalination system based on MD for various capacity with maximum 10m^3/day. All systems can be operated energy self sufficient and almost maintenance free (J. Koschikowski et al. 2009).

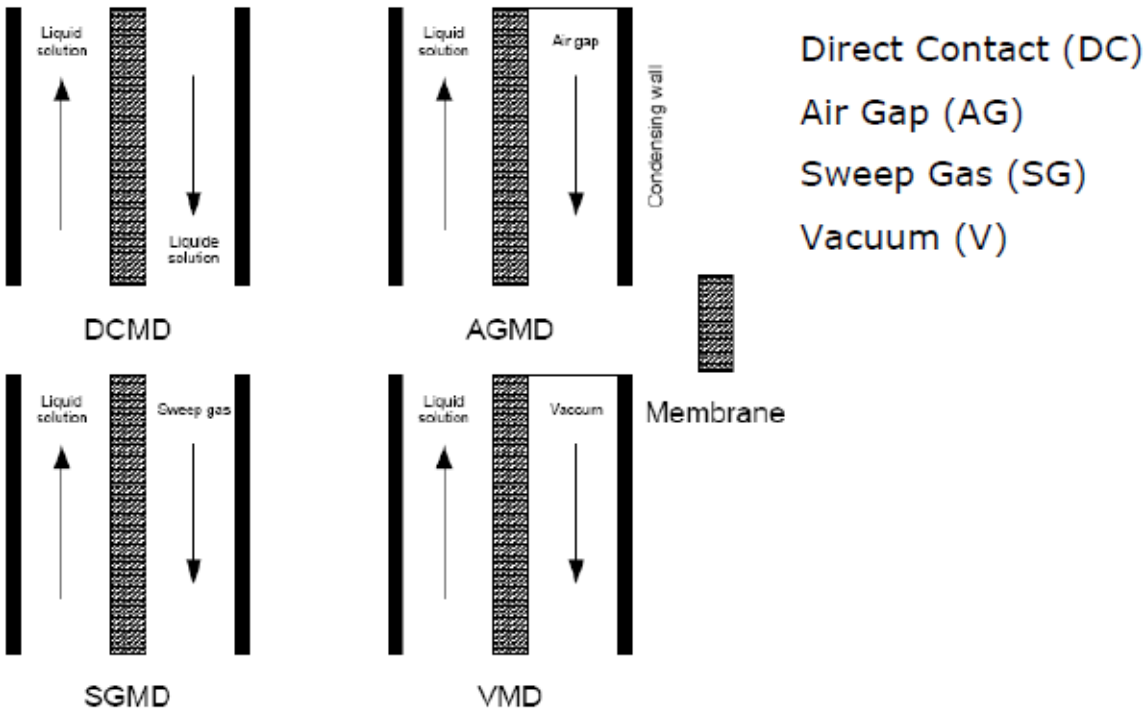

Figure 1. MD configuration (Source: A. Martin, lecture note, KTH)

An extensive analysis of Direct Contact Membrane Distillation (DCMD) by S. Obaidani et al, 2008, reports that exergy analysis, sensitivity study and economical evaluation carried out to assess the feasibility of DCMD process with heat recovery, the estimated water cost is $\$1.17/m^3$ that is comparable to the cost of water produced by conventional thermal processes $\$1.00/m^3$ for Multiple Effect Distillation (MED) and $\$1.40/m^3$ for Multi Stage Flash (MSF). The study also reveals that there are high possibilities of significant savings when a low-grade thermal energy source is used. The study claims that it can approach the cost of water produced by RO that is about $\$0.50/m^3$ (S. Obaidani et al, 2008). As most of the research of technology development is guided by its possibility of commercialization, the decisions of economics are very important for commercialization. Despite the advantages of solar MD system, very few experimental systems have been developed compared with the mature technologies (J. Gavlez et al, 2009). Therefore, the economics, rate of return and payback period are not extensively researched. However, membrane lifetime and plant lifetime are other key factors in determining the water production cost with MD techniques (F. Banat et al, 2008).

Nevertheless, the MD concept seems to be much flexible in its technological association with waste heat as well, that may turn it to be more cost effective solutions in particular climatic and industrial conditions. As RAK-UAE is developing itself as a major tax free industrial/trade/ business zone, the possibility of interlinking of solar thermal with waste heat is extremely high. Therefore, the proposed feasibility study, and later experimental verification may extend positive outcomes leading high possibility of implementation of the concept in this particular region.

As far as space for further technology advancement is concerned, a research article by S. Cerneaux et al, 2009, presents that high salt rejection rates higher than 99% is tested with hydrophobic membranes developed by chemically modifying zirconia and titania ceramic membranes to change their hydrophilic feature into hydrophobic. The study reveals that there is high possibility of improving the ceramic membrane for MD as well. It means that there is high possibility of improving the quality of the membrane that

consequently can improve further applicability of the MD commercialization for sea water desalination.

As far as experiment and prototype testing and performance of MD technology until now is concerned, the KTH, department of energy technology, itself is involved as one of the project partner of MEDESOL (Solar Driven Multistage Membrane Distillation for Desalination) project. The review of the documents of MEDESOL suggests that there is high possibility of its applicability where solar and low grade heat is available.

Research Gap

The technology has not been yet designed and tested taking consideration of the real climatic condition of UAE-RAK. The existing abundance solar resources of the area may be very useful for its performance improvement. Furthermore, the high possibility of developing hybrid unit that consumes both industrial waste heat and solar thermal can lead the study as one of the most ideal case study for MD.

Project Outcome

Design documentation for hybrid solar sea water desalination based on MD technology applicable in UAE climatic condition.

Project Duration

Date of Initiation: February 15, 2010

Date of Report Submission: August 15, 2010

Tasks	Feb	Mar	Apr	May	Jun	July	Aug
Review of literature							
Design of prototype for different desalination options							
Economic Analysis of different prototype options							
Report Preparation / Documentation							

Project location

UAE-RAK

Study location

UAE-RAK and KTH, Department of Energy Technology, Stockholm Sweden as required

Financial Resources and Support

CSEM-UAE, RAK

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