DESALINATION WITH RENEWABLE ENERGY - A REVIEW

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Contents

Summary

Potential renewable energy sources which can be harnessed toward brackish and seawater desalination have been evaluated. These sources of energy, mainly solar, wind and geothermal, have been identified and their suitability for coupling with different desalting technologies have been investigated. Renewable energies are expected to have a flourishing future and an important role in the domain of brackish and seawater desalination. Of special interest are small desalination plants which can be operated with small quantities of energy. Small scale renewable energy driven desalination plants might be the most economical solution for providing portable water to remote and isolated communities where the electric grid and the proper infrastructure are lacking. By exploiting renewable energies for fresh water production, three main problems can be addressed fresh water scarcity, fossil energy depletion and environmental degradation due to gas emissions and hydrocarbon pollution.

1. Introduction

Fresh water is the essence of life and one of the three most important fundamental constituents of the environment; air, water, and soil. These three precious elements and life fundamental necessities on the earth are strongly tied to energy systems and resources since the dawn of life. However, this coupling between energy systems and ecosystems became more pronounced in modern life style with interaction and non-resolved dependency between energy production systems and water resources availability is adding up to the complexity and dilemma of securing sustainable development requirements.

The problem of fresh water shortage is not merely restricted to a few countries. In the Mediterranean region alone, not less than six countries are already below the threshold of 1000 m^3 per year of potable water per capita. Fresh water demand is expected to increase due to population growth and increased standard of living whereas available fresh water from conventional sources is assessed not to be able to cover the total demand. As a result, resorting to non-conventional means of obtaining fresh water such as desalination to make up for the deficit is becoming inevitable.

Human cultures that were strongly tied to abundant water resources in the past are nowadays indispensably relying equally on all natural resources. On the other side, as the fossil fuel reserves worldwide are approaching their expected depletion within few decades, the world has to find new alternative energy sources. Renewable and nuclear energy sources are foreseen for the future to be the main alternatives to compensate for fossil fuel depletion.

Renewable energy sources have received considerable and increasing attention, since they are tremendously non-polluting, inexhaustible, safe, and freely available everywhere in various forms. They are fully satisfying the complex balance between reserving all natural resources on one side and economical development on the other side. Many ambitious research programs, governmental plans in both industrialized and many developing countries, as well as global interests and initiatives reflect their important role and accelerated race with time to realize maturity of such promised systems in the near future. The major RE resources that are considered here are solar energy, wind energy and geothermal energy. The prospects of renewable energy development show a flourishing future- solar energy being the most promising form- has been assessed to be available in huge quantities in many regions of the world. With a higher potential in the southern part of the world solar energy is in perfect synergy with locations where water desalination is most needed. It is also encouraging to know that a large percentage of the population in the south lives in small agglomerations and remote villages making the implementation of small size desalination plants a perfectly adequate solution. These small desalination plants can be operated with minimal energy requirements thus suitable for coupling with renewable energy sources.

Many coastal regions of the world show a high wind energy capacity and hence, various ways of exploitation and utilization of this potential have been proposed. One possible potential application is in desalination of brackish and seawater. In the countries of Mediterranean, for example, where there are quite a few isolated islands, an extensive search for developing desalination methods has started. Since the electrical energy cost in those islands is much higher than that in the mainland, small power substations, which consume mainly Wind potential is more abundant in the northern regions and also in coastal regions of many areas. This form of renewable energy is also suitable for use with small capacity desalination units especially RO type. Nowadays, the wind constitutes the most promising renewable energy source, due to the fact that the cost of the wind kW h competes the cost of the conventional kW h.

Geothermal energy has great potential in greenhouse desalination technology. The former can be used for electricity production, for commercial, industrial, and residential direct heating purposes, and for efficient home heating through geothermal heat pumps. Currently, 24 countries are involved in the generation of electricity using geothermal resources. More than 10,000 megawatts are produced which meet the needs of 60 million people. Iceland is widely considered the role model of the geothermal community. Geothermal energy resources are available in many countries and has been used for power generation for many years. However, their direct use in thermal desalination plants can still give promising results knowing that these desalination processes can be operated at relatively low temperatures.

If desalination of brackish and seawater is emerging as a promising solution to the water scarcity problem, a number of related predicaments have to be urgently addressed so as to guarantee a sustainable and long lasting development of the water desalination industry. Of paramount importance is to make provision for the huge amount of energy required by different desalination technologies. Given the fact that fossil energy reserves are limited and the negative impacts they have on the environment due to pollutants and gas emissions development of renewable energy sources is immediately needed more than ever before.

The scarcity of fresh water resources and the need for additional water supplies is already essential in many arid regions of the world and will be increasingly significant in the future. In addition, there exists rapid degradation in surface and groundwater quality in many countries. The higher standard of living and rapid industrial growth has resulted in a large escalation in water demand. On the other hand, the growth of the population and the consequent food shortage, poverty spreading, increasing unemployment, and unpredicted prices and inflation rate rising, require the expansion of agriculture into arid zones.

The world-wide availability of renewable energies and the availability of mature technologies in this field make it possible to consider the coupling of desalination plants with renewable energy production processes in order to ensure the production of water in a sustainable and environmentally friendly scheme for the regions concerned. Recently, considerable attention has been given to the use of renewable energy as sources for desalination, especially in remote areas and islands, because of the high costs of fossil fuels, difficulties in obtaining it, attempts to conserve fossil fuels, interest in reducing air pollution, and the lack of electrical power in remote areas.

The interface between the renewable energy system and the desalination system is where the energy generated by the RE system is made available to the desalination plant.

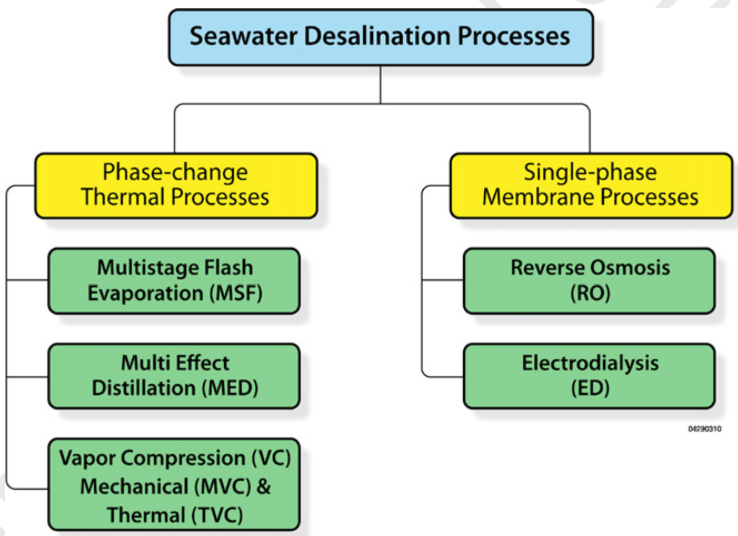

Figure 1 Commercial desalination processes

A desalting device essentially separates saline water source of high salinity into two streams: one with a low concentration of dissolved salts (the fresh water stream) and the other containing the remaining dissolved salts (the concentrate or brine stream). The device requires energy to operate and can use a number of different technologies for the separation process. This energy can be in different forms such as thermal energy, electricity or shaft power. There are a number of commercially available desalination processes that can be combined with renewable energy systems (RES). Figure 1 shows these desalination processes. As can be seen, these desalination processes are divided into phase-change thermal processes (they are also called distillation processes) and single-phase membrane processes. The phase-change processes are constitute the MSF process, the MED process and the VC process which constitute the MVC and TVC processes. The single-phase membrane processes constitute the RO process and the ED process. Phase-change processes require both electrical (or mechanical) energy and thermal energy for their operation whereas single-phase membrane processes require only electrical (or mechanical) energy for their operation. RO process can be used to desalt either seawater or brackish water while ED is only used to desalt brackish water. All processes require a chemical pretreatment of raw feedwater to avoid scaling, foaming, corrosion, biological growth, and fouling and also require a chemical post treatment of the processed water.

2. Commercial Desalination Processes and Their Energy Consumption

Desalination processes require significant quantities of energy to achieve separation of salts from saline water. This is highly significant as it is a recurrent cost, which few of the water-short areas of the world can afford. Many countries in the Middle East, because of oil income, have enough money to invest in and run desalination equipment. People in many other areas of the world have neither the cash nor the oil resources to allow them to develop in a similar manner. The installed capacity of desalinated water systems in year 2008 is about 53 million m^3/day[……], which is expected to increase drastically in the next decades. The dramatic increase of desalinated water supply will create a series of problems, the most significant of which are those related to energy consumption and environmental pollution caused by the use of fossil fuels. It has been estimated by Kalogirou (2005) that the production of 25 million m^3/day requires about 230 million tons of oil per year. Given concern about the environmental problems related to the use of fossil fuels, if oil was much more widely available, it is questionable if we could afford to burn it on the scale needed to provide everyone with fresh water.

Given current understanding of the greenhouse effect and the importance of CO_2 levels, this use of oil is debatable. Thus, apart from satisfying the additional energy demand, environmental pollution would be a major concern. If desalination is accomplished by conventional technology, then it will require burning of substantial quantities of fossil fuels. Given that conventional sources of energy are polluting, sources of energy that are not polluting will have to be developed. Fortunately, there are many parts of the world that are short of water but have exploitable renewable sources of energy that could be used to drive desalination processes.

2.1. Description of the Commercial Desalination Processes

This sections explains briefly the different commercial desalination processes [Eltawil et al. (2008)].

2.1.1. Distillation Processes

Distillation processes mimic the natural water cycle as saline water is heated, producing water vapor, which in turn is condensed to form fresh water. These processes include: multi-stage flash distillation (MSF), multi-effect distillation (MED), and vapor compression distillation (VC). Forty percent of the world's desalination capacity is based on the MSF desalination principle. However, other distillation technologies, such as MED and VC distillation, are rapidly expanding and are anticipated to have a more important role in the future as they become better understood and more accepted. These processes require thermal or mechanical energy to cause water evaporation. As a result, they tend to have operating cost advantages when low-cost thermal energy is available.

1. Multi-stage flash distillation (MSF)

In MSF, seawater feed is pressurized and heated to the plant's maximum allowable temperature. When the heated liquid is discharged into a chamber maintained at slightly below the saturation vapor pressure of the water, a fraction of its water content flashes into steam. The flashed steam is stripped of suspended brine droplets as is passes through a mist eliminator and condenses on the exterior surface of the heat-transfer tubing. The condensed liquid drips into trays as hot fresh-water product. Fig. 2 is a diagram of a typical MSF unit.

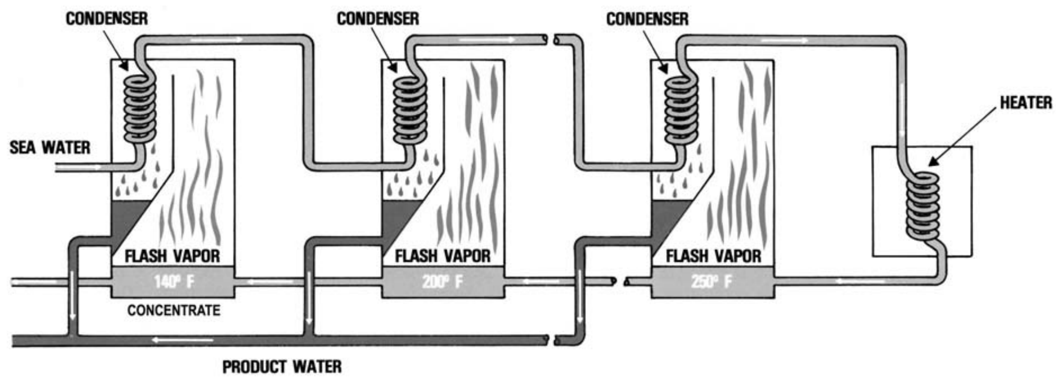

Figure 2 MSF process flow diagram

2. Multi-effect distillation (MED)

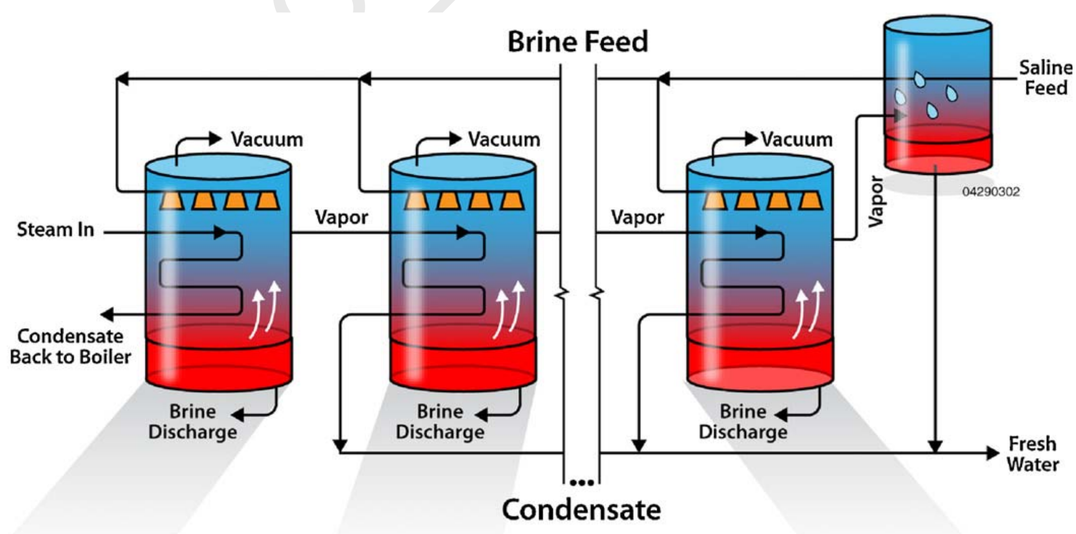

Figure 3 MED process flow diagram

MED units operate on the principle of reducing the ambient pressure at each successive stage, allowing the feed water to undergo multiple boiling without having to supply additional heat after the first stage. In this unit, steam and/or vapor from a boiler or some other available heat source is fed into a series of tubes, where it condenses and heats the surface of the tubes and acts as a heat-transfer surface to evaporate saline water on the other side. The energy used for evaporation of the saline water is the heat of condensation of the steam in the tube. The evaporated saline water—now free of a percentage of its salinity and slightly cooler—is fed into the next, lower-pressure stage where it condenses to fresh-water product, while giving up its heat to evaporate a portion of the remaining seawater feed. Fig. 3 is a diagram of an MED unit.

3. Vapor-compression distillation (VC)

The VC distillation process is generally used for small- and medium-scale seawater desalting units. The heat for evaporating the water comes from the compression of vapor, rather than from the direct exchange of heat from steam produced in a boiler. The plants that use this process are generally designed to take advantage of the principle of reducing the boiling-point temperature by reducing the pressure. Two primary methods are used to condense vapor so as to produce enough heat to evaporate incoming seawater: a mechanical compressor or a steam jet. The mechanical compressor (MVC) is usually electrically driven, allowing the sole use of electrical power to produce water by distillation (Fig. 4).

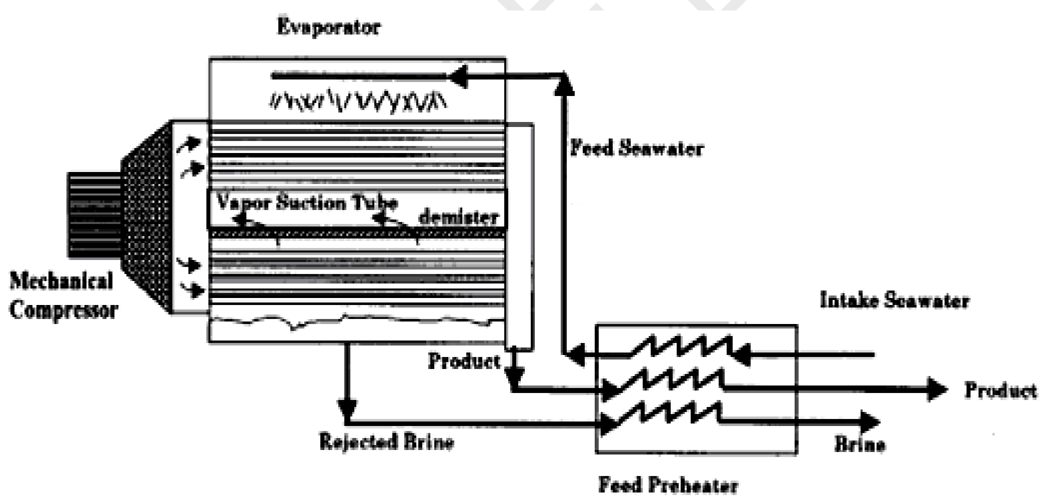

Figure 4 Mechanical vapor compression (MVC) process

With the steam jet-type of VC unit, also called a thermo compressor (TVC), a Venturi orifice at the steam jet creates and extracts water vapor from the main vessel by creating a lower ambient pressure in the main vessel. The extracted water vapor is compressed by the steam jet. This mixture is condensed on the tube walls to provide the thermal energy (heat of condensation) to evaporate the seawater being applied on the other side of the tube walls in the vessel (Figure 5). VC units are usually built in the range of 20–2000 m^3/d (0.005–0.5 mgd), and they are often used for resorts, industries, or other sites where fresh water is not readily available.

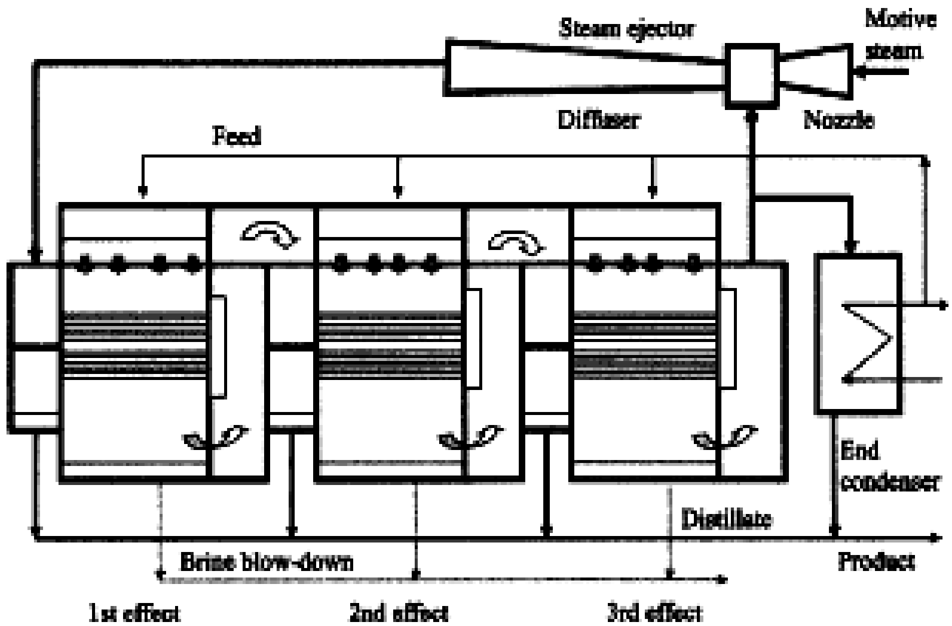

Figure 5 Multi-effect thermal vapor compression desalting unit

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