International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 4 Issue 03, March-2015

A Review on Solar Powered Desalination Systems

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***Abstract*—Desalination is most important and traditional process to get the potable water. Day to day the demand of fresh and potable water is increased, so that desalination is important and gained more attention. In conventional process desalination for heating process fuel is used as the thermal source but the due to rapid decreas in the fuel storage it is necessory to go with the renewable energy for the desalination process. Traditionally fuel is used which emits the pollutants after burning and it is harmful to environment and human being also. This paper reviews the different types of desalination systems which are powered by solar energy. The solar powered desalination systems are cost effective and also give high rate of water production. The inlet temperature of water is effects on the daily water production rate, efficiency of the system and gained output ratio. Solar powered desalination systems are not commercialy used yet, but it is the emerging low cost energy can be used for desalination in future.**

Keywords—Solar, Desalination

I. INTRODUCTION

Water is the most important substance in a life of all survivals. As the population of world increasing rapidly the demand of potable water is also increased. According to the survey of World Health Organization (WHO) in all over world one billion people do not get clean and fresh water. 41% of world population lives in water stressed areas [1]. About total Earth's surface three fourth surfaces is acquired by water out of that 97% is sea water only 3% availability of fresh water [2]. Most of the fresh water is locked in ice, so an average only 1% percent of fresh water is useful for humans and animals. There for the main source of water is ocean, which having the 97% total water. And this water is saline, so that the desalination of sea water is important. We can use that fresh water in day to day life for biological, agricultural and industrial purpose [13, 20]. The various desalination systems used are, multi-stage flash distillation (MSF), multi effect desalination (MED), low temperature desalination (LTD), desalination by humidification and dehumidification (HD), membrane distillation (MD), electrodialysis (ED), reverse osmosis (RO), mechanical vapor compression (MVC) desalination [3].It is estimated that about 8.78 million tons of oil per year is required to produce by desalination 1 million/m^3/day of fresh water, which indicates the importance of finding suitable alternative energy resources for the desalination systems [4].

There are various alternative renewable sources for the desalination. Among all those solar energy has the potential which gives future energy demand. Due to increase in population of developing countries need for the potable water is also increased. These countries cannot afford to use conventional desalination systems. So these countries can use solar powered desalination systems. These countries are having higher solar radiation also. For example the India the average daily solar radiation in India is 4–7 kWh/m^2 compared with the global average of 2.5 kWh/m^2 .Therefore, solar energy driven/assisted desalination is becoming more viable despite its high capital cost [4].

II. SOLAR POWERED SYSTEMS

A. *Solar powered MSF:*

After RO the MSF is second which has largest installed desalination capacity. For the production of distilled water MSF consumes large thermal energy, and electric energy for the pumping work is required.Fig.1 shows the MSF system connected with the solar heat source and electricity source. Power grid is also connected to the thermal system through the heat engine so that it provides heat and electricity at the same time.

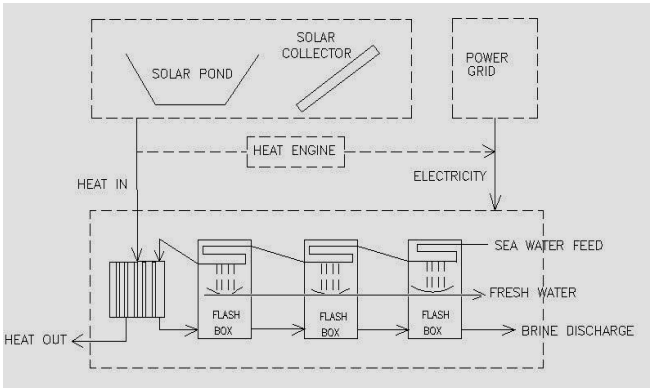

Fig.1. Solar powered MSF system.

Fig.1 shows the desalination system operated on the solar pond. The solar pond is act as a heat source for the system. Solar pond having three layers/zone according to the concentration of salt. From the middle layer top to the bottom the concentration of the salt is increases. Heat is collected and stored at the bottom layer. In this system the sea water is passed through the number of stages of flash box. MSF is operated in the range of 90-110^{0}C and solar pond operated at 35-95 ^{0}C [4]. So that first step is to transfer liquid to liquid heat trough heat exchanger. There are also other solar methods for MSF desalination such as collector power MSF system, pv based MSF system etc.

B. *Solar powered MED:*

It is similar to the solar powered MSF system; it also required both thermal energy and mechanical energy. There are three configuration of MED system namely; forward feed, backward feed and parallel feed. Fig.2 shows the schematic diagram of solar powered MED system with parallel feed. In this system the sea water is delivered to the effects which are the low pressure vessels with a successively sequence. The heat from source is supplied to the first effect and generated vapor of previous effect supplies its latent heat of condensation to the next effect. The MED system normally required 2-14 numbers of effects [4].

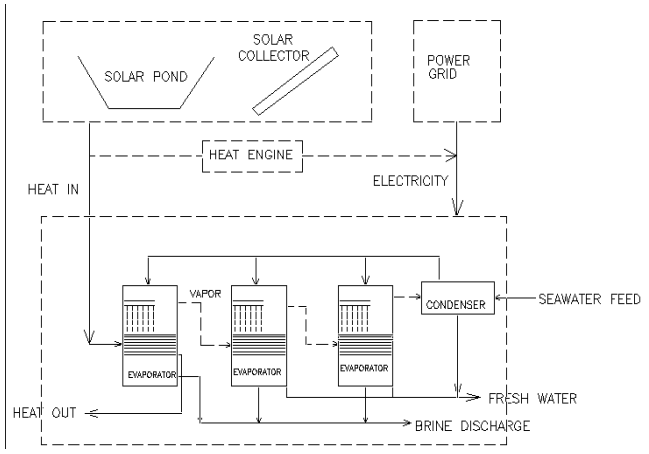

Fig.2 Schematic diagram of solar powered MED system

C. *Solar powered humidification-dehumidification desalination system:*

This process is run on the same principle of the natural water cycle. Fig.3. shows the schematic diagram.

The working procedure of the system is as follows. First, brackish water or sea water is heated by the solar collectors as much as possible. Then, the hot water is injected to the top of the evaporation tower. A pulverizer with a special shape is used to assure a uniform pulverisation of the hot water in all the sections of the tower. Hot and saturated air mixes with the rising air current toward the condensation tower. Then it condenses in contact with the cold condensation plates. The circulation of the air in the evaporation tower may occur in natural convection or in forced convection with two functioning modes: closed air circuit or open air circuit [5].

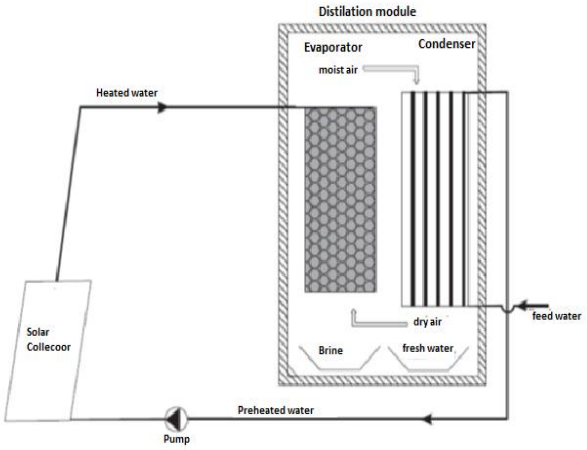

Fig.3. Schematic diagram of HDH water desalination system

D. *Solar powered electrodialysis desalinatoin system:*

Electrodialysis is the process mostly used for the desalination of brackish or sea water. In this system the DC electric field is used for the removal of salt from the brackish or sea water. Fig. 4 shows the schematic diagram of experimental setup of electrodialysis desalination system. This system requires DC power so that system required AC to DC converters for the desalination process. So that the solar photovoltaic is most attractive alternative for conventional AC to DC converter as the solar energy is available throughout the year.

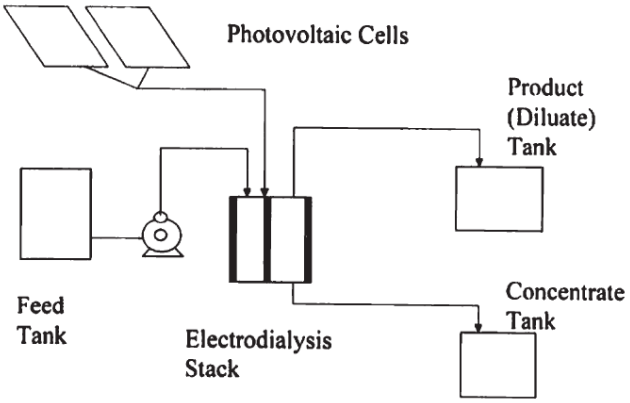

Fig.4. Solar powered Electrodialysis desalination system.

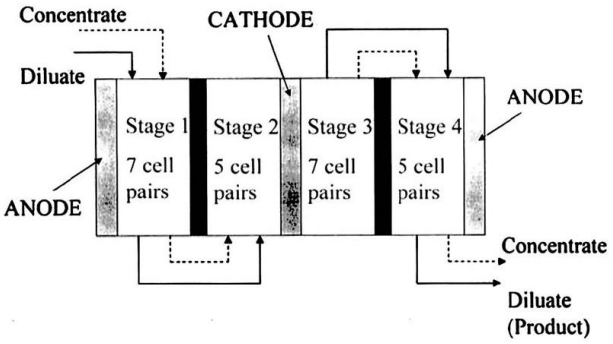

Fig.5. Electrodialysis stack.

The working principle of this system is as follows. The brackish water is passes through the pairs of cation and anion membranes. The cation (positive ions) migrates from the brackish water towards the negative electrode through the cation membranes which allow only cations to pass. On the other hand, the anions migrate towards the anode through the anion membranes. In an actual process, a large number of alternating cation and anion membranes are stacked together, separated by flow spacers which are plastic sheets that allow the passage of water. The streams in alternating flow spacers are a sequence of diluted and concentrated water which flow in parallel to each other. The new technology called electrodialysis reversal (EDR) is used for the prevention of scaling, in which polarity of electric field is reverse for about 20 min. [6].

E. Solar powered RO desalination system:

Fig.6. gives the schematic diagram of the solar powered RO desalination system. If we consider the term capacity, RO is the largest desalination system in the world. This system requires of electricity from the PV panel or mechanical energy from the solar pond or from collector to run the system. Solar powered RO system is more energy efficient than the phase change thermal process but it requires extensive water treatment. Osmosis is the natural phenomenon in which the salted water is passes through a membrane from less salt concentration to the more salt concentration. For the reverse flow of water the pressure required of the sea water is more than the atmospheric pressure. And it is typically of 2500 Kpa [4].

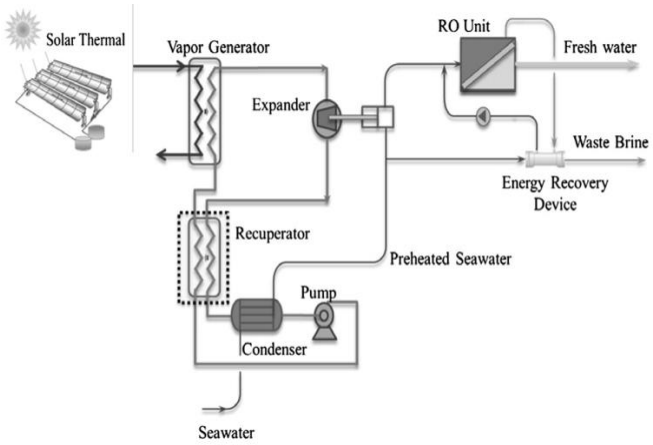

Fig.6. Solar powered RO desalination system.

Among all the process of solar powered RO desalination system the PV based RO desalination system is widely used, because both PV and RO are modular and easily scalable.

F. Solar still:

Solar still is also called as the direct still. The heat collection and distillation processes occur within the same system where solar energy is used directly for distillation by means of the greenhouse effect. Water vapor rises to the transparent cover by natural convection and condenses there. A solar still output might be affected by many factors including brine depth, vapor leakage, thermal insulation, cover slope, shape material, climate The latent heat is normally wasted on the cover, therefore the system efficiency is relatively low with a daily production of about 3–4 l/m^2 [4].

G. Solar powered Adsorption desalination system:

Adsorption desalination is an emerging low cost thermal desalination system [8]. Fig.8. shows the solar powered adsorption desalination system.

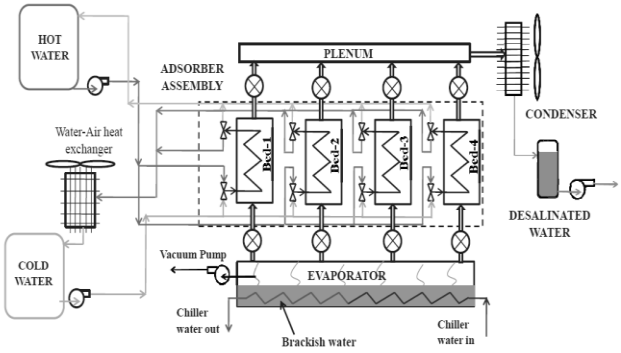

Fig.8. Solar powered adsorption desalination system.

Working principle of adsorption desalination system is as follows. In this system mostly silica gel is used as the adsorber, because it is nontoxic and ecofriendly. The sea water is evaporating in the flash evaporator. This vapor is absorbed by the adsorber in adsorber bed. Then the hot water from the solar heat source is passed through the adsorber bed and adsorbed vapor get evaporated and going to the condenser where vapor get condensed, and forms potable water at the end. Again cold water is passed through the adsorber bed so that bed can regain its adsorption capacity [7].

The minimum number of adsorber bed used is one. But for increasing production capacity we can increase the adsorber bed so that half beds are adsorb vapor and half beds desorbs adsorb vapor. It decreases delay period hence increasing production rate of potable water.

III. LITERATURE REVIEW

S.A. El-Agouz et.al [9], conducted the experiment on the solar desalination system using spray evaporation in arid area with 1 m^2 solar water collector area. They studied the effect of water inlet temperature on the various factor such as productivity, efficiency, productivity rate, Gained Output Ratio (GOR) and cost potable water per liter of the desalination system. They are found that as increase in inlet temperature of water is directly proportional to the productivity, efficiency, productivity rate, GOR.

Maximum daily production rate is increased up to 9 l/m^2. Maximum day efficiency is about 87%. And cost of potable water per liter is $0.029.

Saffa Riffat et.al [16], performs the experiment on the v-trough solar concentrator for water desalination application. It is introduced as new type of collector. By experimentation they found that the water is heated up to 100 ^{0}C, and the efficiency is maximum reached up to the 38%. The new VTC is more economical in terms of cost and land requirement than the FPC and other type of collectors. Fig.11. shows the schematic diagram of the v-trough collector for desalination application.

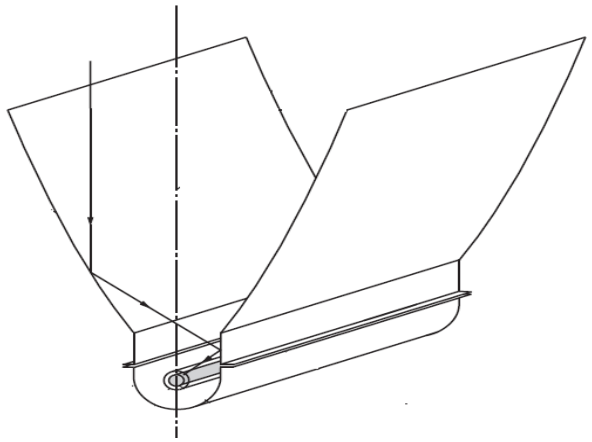

Fig.10. V-trough collector

Xiaohua Liu et.al [10], conducted the experiment on the solar desalination system with evacuated tube collectors and use multi-effect distillation system. They do the thermal and economic analysis of system and they found that,

1. With the increasing of heating steam temperature of the first effect, the area of evaporator and fresh water cost reduce the volume of storage tank increases, but fresh water production and fresh water production per unit of collector area all change slightly.
2. With the increasing of the number of effects, the volume of storage tank changes slightly, but the area of evaporator and fresh water production increase, fresh water cost reduces greatly.
3. Among the cost constitution of ETC solar desalination system, the proportion of the cost of evacuated tube collector is the largest (31%), then the cost of civil installation and auxiliary equipment and the cost of manpower is second (15%).

Mahmoud Shatat et.al [11], conducted the experiment on the small scale solar water desalination system for remote and semi-arid region. Economic study is done on the system and they had gives the conclusion that the cost of potable water production for this system is reduced to the 8 US$/m^3 from the 11 US$/m^3. The area used for the solar collector is 3 m^2.

Esmail M.A. Mokheimer et.al [12], conducted experiment on the hybrid wind–solar-powered reverse osmosis water desalination system for Saudi Arabia. They check the performance of the system and calculate the cost required for getting potable water production. And the result is the cost for the water desalination is between the range of $3.693/m^3 to $3.812/m^3 which is less than the all other desalination systems.

Edward K. Summers et.al [14], perform the experiment on humidification and dehumidification desalination system using air-heating solar collector. In this experiment they check the performance of the system by using different type of air heating solar collector such as use of highly trans missive polymer film, low iron glass, very absorptive absorber etc. in the collector. A collector with a double glazing, a highly roughened absorber, and a carbon black coated absorber, results in a collector efficiency of 58% at a normalized gain of 0.06 K m2 /W.

Mohammad Abutayeh et.al [15], conduct the experiment on the solar flash desalination under the condition of hydrostatically sustained vacuum. They did the simulation work on this system and find the physical properties of the system. The vacuum in the system is maintained by the internal hydrostatic pressure balanced by the atmospheric pressure. The simulation results show that running the system at higher flash temperatures with a fixed flash chamber size will result in faster vacuum erosion, increased solar collection area, increased boiling point elevation, faster equilibrium attainment, shorter run time, and less production, which is leading to less overall evaporation.

Farshad Farahbod [21], performs experimental and mathematical investigation on solar pond desalination. In this investigation solar pond desalination is considered as the zero discharge desalination process. The studied parameters are effect of salinity content, temperature of water, production rate, condensation rate etc. They observe that as the salinity of brackish water increases the potable water production rate is also increases as the condensation rate increases. Evaporation method used in this experiment. By theoretical analysis the value of evaporation rate with maximum deviation is 7%. The cost of potable water production is ranges from 0.62 US $/m^3 to 3.5 US $/m^3.

CONCLUSION

The conventional desalination systems are energy intensive process. Solar energy could be used for desalination of water as solar energy is available in abundant, and as its technical feasibility is more [4]. In conventional water treatment process the fuel consumption is more, so for avoid this solar powered desalination gain more attention, as sources of fuel are limited. The production rate of water by using solar powered desalination is more as compared to the conventional water desalination process [21]. With the proper solar radiation data collection and modeling after few years the solar powered desalination is the best option for convention desalination system.

A. Abbreviation:

MFS	- multi-stage flash desalination
MED	- multi effect desalination.
RO	- reverse osmosis.
HDH	- humidification-dehumidification
GOR	- gained output ratio.
VTC	- V-trough collector.

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