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Hybrid Solar Desalination and Water Heating System: A Review

S.B.Nithyananth[1], S.Gopala Krishnan[2]

[1]Assistant Professor (SRG), [2]PG Research Scholar, Department of Mechanical Engineering, Kumaraguru College of Technology, Coimbatore (India)

ABSTRACT

The hybrid character of a solar desalination system consisting of a "Green House"- type conventional solar still coupled with a solar collector field and hot water storage tank was reviewed. The solar desalination systems are energy intensive, which consume high grade energy like gas, electricity, oil and fossil fuels. A review of these processes lead to carbon footprints, which causes depletion of ozone layer as well as health hazards on mankind. It is also lead to global warming which is the burning topic and becomes threat to life sustainability. The potential of harnessing solar energy is most efficient and effective for heat to heat conversion. This hybrid system shows significantly higher distilled water output compared with that of an uncoupled still, and moreover it has the advantage of supplying hot water from its storage tank. Effective hybrid system is performed concerning reduction of produced distilled water caused by storage tank hot water draw-off of different volumes at the end of the day. The pursuit of hybrid systems is an important research topic as it allows for further development of solar desalination technologies while providing an immediate solution that increases the use of solar power.

Keywords: Solar still; Hybrid desalination system; Harnessing, solar energy; Hot water.

I. INTRODUCTION

Water is the most important substance in a life of all survivals. When the population of world increasing rapidly the demand of potable water is also increased more. So freshwater scarcity is associated with large quantity of solar resources. It seems also logical and attractive to associate those two parameters for countries where grid electricity is not spread widely and with easy access to seawater or brackish water. Solar desalination is not a new concept or an idea: it has been known for many ages, antique sailors used to desalt water with simple and small sized solar stills during that period. It’s also a fact that production of fresh water requires a large amount of energy as a 1000 m3 of freshwater per day which requires 10,000 tons of oil/year. Though solar energy is often called as a ‘Free Energy’ and the solar desalination water is a promising alternative solution for supplying relatively to small communities, remote areas or islands with fresh water. Solar stills present some specific advantages for their use in these areas such as ease of construction using locally available materials, minimum operation and maintenance requirements and friendliness to the environment. Their main disadvantage, however it is the low output in distilled water when compared with other desalination system technologies. However, it has been proven that an increase of saline water temperature leads to significantly higher outputs.

IJARSE
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The sun gives us life and energy, today our thirst for newer clean renewable sources of energy. Our nation is blessed with large amount of solar energy; it receives solar radiation for at least 300 days in a year i.e. more than 3000 h of sun shine in a year, almost all regions of India receives more than adequate solar radiations. The annual average of direct normal irradiation varies within India like Rajasthan, Karnataka and Tamil nadu region receives highest DNI annual average. In India we have the average daily solar radiation is 4–7 kWh/m2 when compared with the global average solar radiation of 2.5 kWh/m2 .Some of the countries like Australia, South Africa, Chile, Mexico, Algeria, Libya Egypt, Namibia, Botswana and Zimbabwe receives highest solar energy. For regional average South Asian region is after Middle East, North Africa region in between tropic of cancer and tropic of Capricorn region receives highest solar energy isolation. The water demand is increasing rapidly than the sustainable level and desalination is the best method to provide the shortfall of water in future.

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. The application of solar energy includes water heating in the domestic sector, health institution and tourism sector as one of the popular devices that harnesses solar energy which can replace the electric water heater is the solar water heater and its system is called solar water heating system Therefore, solar heating system driven/assisted desalination is becoming more viable despite its high capital cost, this paper provides a review of various solar collectors in solar water heating systems and its applications. The review consists of an introduction to solar water heater systems including the active and passive systems, basic components of solar water heating and its latest researches and advances of solar water heater associated with solar desalination system.

II. DESALINATION TECHNOLOGIES

Desalination was first used by Greek sailors in the 4th century BC to evaporate seawater and create drinking water. It is by definition a process removing minerals and salts from saline water to produce freshwater, that can be used for human use or irrigation. Desalination uses the principle of osmosis to remove salt and other impurities, by transferring water through a series of semi-permeable membranes. Thermal desalination uses heat, often waste heat from power plants or refineries, to evaporate and condense water to purify it. and in order to improve the efficiency of the plants.

There are two main types of desalination technologies –

a) Membrane –Reverse Osmosis

b) Thermal: MED – Multi effect distillation
MSF – Mult Stage flash process

a) REVERSE OSMOSIS

RO desalination technology was initially developed in the late 1950s, and has now evolved into the leading desalination technology globally. There are many different processes used in RO desalination, and a variety of factors come into play when selecting the appropriate solution for each situation – the quality of the source

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water, the desired quantity and quality of the water produced, pretreatment, energy requirements and disposal of concentrate. Key features of the RO process are the following:

- Low energy consumption
- Easy and ready to use : immediate stop and start
- Needs important pre-treatment : pre-filtration and chemical (anti-scalant) to avoid fouling on the membrane
- Outlet salt concentration around 500 ppm

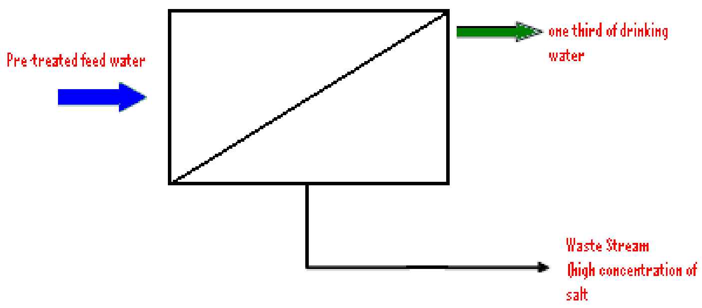

Fig: 1 Schematic layout of Membrane Reverse osmosis system.

b) MULTI EFFECT DISTILLATION

Multiple-effect distillation (MED) is a distillation process often used for sea water desalination. It consists of multiple stages or "effects". In each stage the feed water is heated by steam in tubes. Some of the water evaporates, and this steam flows into the tubes of the next stage, heating and evaporating more water. Each stage essentially reuses the energy from the previous stage. It can be seen as a sequence of closed spaces separated by tube walls, with a heat source in one end and a heat sink in the other end. Each space consists of two communicating subspaces, the exterior of the tubes of stage n and the interior of the tubes in stage n+1. Each space has a lower temperature and pressure than the previous space, and the tube walls have intermediate temperatures between the temperatures of the fluids on each side. The pressure in a space cannot be in equilibrium with the temperatures of the walls of both subspaces. It has an intermediate pressure. Then the pressure is too low or the temperature too high in the first sub space, and the water evaporates. In the second subspace, the pressure is too high or the temperature too low, and the vapor condenses. This carries evaporation energy from the warmer first subspace to the colder second subspace. At the second subspace the energy flows by conduction through the tube walls to the colder next space.

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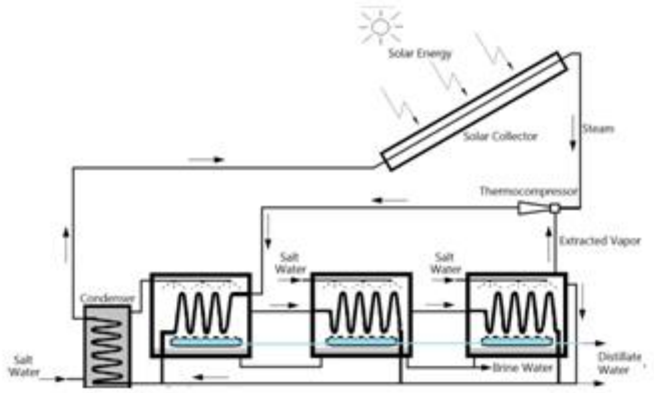

Fig: 2 Schematic layout of Multi effect distillation.

b) *MULTI* STAGE FLASH

Multi-stage flash distillation (MSF) is a water desalination process that distills sea water by flashing a portion of the water into steam in multiple stages of what are essentially countercurrent heat exchangers. The plant is operating in steady state, feed water at the cold inlet temperature flows, or is pumped, through the heat exchangers in the stages and warms up. When it reaches the brine heater it already has nearly the maximum temperature. In the heater, an amount of additional heat is added. After the heater, the water flows through valves back into the stages that have ever lower pressure and temperature.

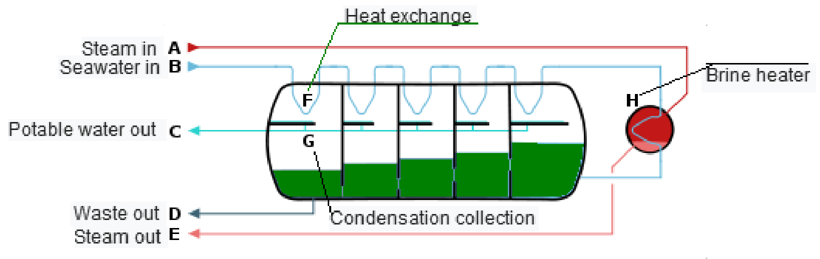

Fig: 3 Schematic layout of Multi Stage Flash

III. DEVELOPMENT OF SOLAR WATER HEATING SYSTEM (SWH)

The solar water heating system has been around for many years and it is the easiest way to tap the solar energy to save the money. In olden days they would place a cooking pot filled with coldwater in the sun all day to have heated water in the evening. The first SWH that resembles the concept, and is still in use today, was a metal tank. It was painted black and placed on the roof where it was tilted toward the sun, usually black body absorbs more heat energy. A sun-facing collector heats a working fluid that passes into a storage system for later use. Solar water heaters are active and passive. They use water only, or both water and a working fluid. They are heated directly or via light-concentrating mirrors. They operate independently or as hybrids with electric or gas heaters. In large-scale installations, mirrors may concentrate sunlight onto a smaller collector. The concept really worked but it usually took all day for the water to heat and then as soon as the sun went down, it cooled off quickly because the tank was not insulated. Subsequently, solar water heater is a device of a solar water heating system that is rightly needed in every home as it has many benefits to people, community and also the

IJARSE
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environment which functions to heat water and produce steam for domestic and industrial purposes using solar energy. This system plays a vital role in collecting energy from the sun through its panels or tubes, followed by the production of hot water. Solar water heater is generally installed at the terrace or where sunlight is available and heats the water during the day. Then, the hot water will be stored in an insulated storage tank and ready to be used for household utilities especially in the mornings. Indeed, the solar water heater had effectively entered the global market commercially.

Fig: 4 Solar water heating system (SWH)

3.1 Solar Water Heating System (SWH)

The solar water heating system uses natural solar thermal technology which is where solar radiation is converted into heat and transmitted into a transfer medium such as water, antifreeze or air. The SWH is feasible and replaces the electricity and it is otherwise called as a "Free energy". These systems can be classified into two main categories; active system and passive system as shown in Fig. 5. The active system can be divided into two which are the open loop and close loop system whereas the passive system uses the system of thermo siphon and integral collector storage (ICS). The solar water heating system proves to be an effective technology for converting solar energy into thermal energy. The efficiency of solar thermal conversion is around 70% when compared to the solar electrical direct conversion system that has an efficiency of only 18%.

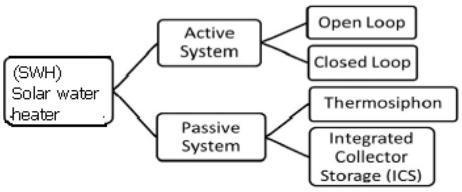

Fig: 5 Categories of Solar water heating system (SWH)

3.1.1Active System

Active solar heating is a more involved process than passive solar heating. And it is use solar energy to heat a fluid either liquid or air and then transfer the solar heat directly to the interior space or to a storage system for later use. If the solar system cannot provide adequate space heating, an auxiliary or back-up system provides the additional heat. In combination with conventional heating equipment, a SWH provides the same levels of comfort, temperature stability and reliability as a conventional type system. A building that has been heated is often referred to as a "solar house". Active solar heating systems operate as follows and shown in Fig:6

IJARSE
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- Flat plate collectors are usually placed on the roof or ground in the sunlight. The top or sunny side has a glass or plastic cover to let the solar energy in. The inside space is a black (absorbing) material to maximize the absorption of the solar energy.
- Cold water is drawn from the storage tank by pump and is pumped through the flat plate collector mounted on the roof of the house.
- The water absorbs the solar energy and is returned back to the tank.
  Warm water from the tank is pumped by pump though the heating coil.

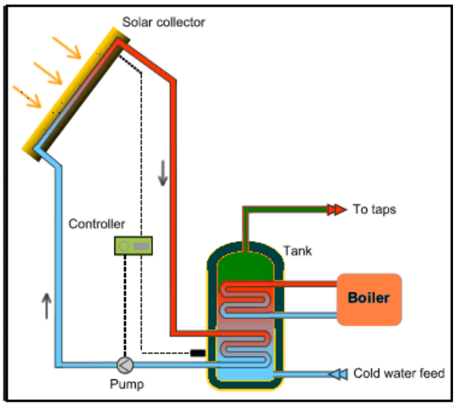

Fig: 6 Active Solar water heating system

3.1.2 Passive System

Passive solar water heating systems are typically less expensive than active systems, but they're usually not as efficient. The passive system uses the method of natural convection heat transfer and without mechanical devices to circulate water or transfer fluids between a collector and an elevated storage tank which is placed above the tank as shown in Fig. 7. In this system, if the fluid is gradually heated up, it will result in the decreasing of the fluid density. Starting with the collector, for example the flat plate collector (FPC), it collects the radiation from the sun and at that moment, the fluid in the collector will absorb the heat, causing the fluid density to decrease as well as affecting the upsurge of fluid to the top of the collector and gushing into the storage tank. However, passive systems can be more reliable and may last longer.

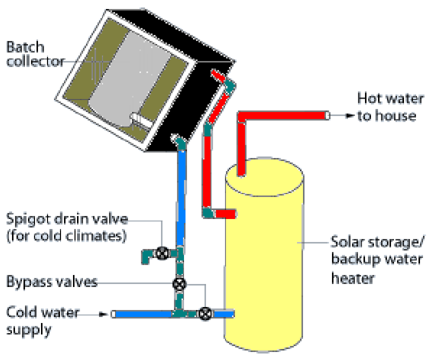

Fig: 7 Passive Solar water heating system

IJARSE
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3.1.2.1 Thermosiphon

The best examples of passive systems are the thermosiphon in Fig. 7 and the integrated collector storage (ICS).It uses this type of roof mounted flat plate collector, storage tank and connecting pipe together. However, caution and care should be taken when installing such a system as the combined weight of the solar collector, storage tank and the water itself might be too much for the design of the supporting roof. Moreover, the thermosiphon's concept is just simple and requires less maintenance due to the absence of control forces and instrumentations. The efficiency of a collector depends on the difference between collector and ambient temperature; the greater the difference between collector temperature and ambient temperature, the lower the intensity of solar radiation. The thermosiphon system is the most common type of solar water heating system in the market and most commercially available.

IV. CONCLUSIONS

This paper has reviewed the state of the art solar energy applications, with the focus on the solar water heating system that can be divided into two systems: the active system (open loop and closed loop) and the passive system (thermosiphon and ICS). This paper also reviewed solar water heaters that have three basic components: solar collector, storage tank and heat transfer fluid and its advances in research. After the extensive literature reviewed, it was found that 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. 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. With the proper solar radiation data collection and modeling after few years the hybrid solar powered desalination and water heating system is the best option for convention desalination system.

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