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ADVANCES IN HYBRID SOLAR DESALINATION SYSTEMS: A REVIEW

SNEHA D. DESHMUKH, DR. SURENDRA R. KALBANDE

Department of Unconventional Energy sources and Electrical Engineering, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola

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Abstract: *As available water present on earth is about 97 % salty. Hence availability of pure water is main problem in many regions of the world. In concern of this problem solar water distillation is main process to get purified water and the regions which are having water scarcity are those which are having high solar radiation. So solar distillation technique is one of the way to produce purified water by harnessing solar radiation. This paper focuses on different hybrid solar distillation techniques used for water purification to enhance the productivity. Hybrid desalination techniques used for dual purpose which depends on system incorporated with conventional solar still.*

Keywords: *Solar distillation system, desalination, photovoltaic thermal collector, solar still*

Corresponding Author: MS. SNEHA D. DESHMUKH

Co Author: DR. SURENDRA R. KALBANDE

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INTRODUCTION

Since recent years drinking water resources have been depleted due to increase in worldwide population, increasing the standards of living, polluting by industrial wastes and over-exploitation and therefore the freshwater shortage is becoming one of the main issues in the world (Delyannis, 2003; Tiwari et al., 2003; Ranjan and Kaushik, 2013). There is a need to develop self-sustained technologies and systems to meet the increasing fresh water demand.
There are some available techniques for water purification such as multistage flash (MSF), multi-effect distillation (MED) and reverse osmosis (RO) (Ranjan and Kaushik, 2013; Kalogirou, 2005). As the cost and low availability of energy in remote areas hence a free source of energy such as solar energy has been used for water distillation.

Solar distillation systems are mainly classified as active and passive solar still. In passive solar still heat collection and distillation occurs in same equipment but in active solar still additional heat source is provided to conventional passive solar still such as solar collector (Bacha et al., 2007; Voropoulos et al., 2003) Sun tracking sytems (Abdallah and Badran, 2008). This paper deals with the different hybrid solar distillation techquines used to improve the performance of solar still.

Hybrid solar distillation systems

Active solar still integrated with two hybrid PVT collectors

The experimental set up has two flat plate collectors which are connected in series and it is further connected to the basin of solar still with the help of insulated pipes. Here, both flat plate collectors are partially covered by photovoltaic module (Chow et al., 2006). The electrical energy generated by PV module is supplied to DC motor water pump which compels the water to circulate under forced mode of operation and hence overcomes the pressure drop in collectors and piping arrangement. The radiation directly absorbed by the blackened surface of the collector, the thermal convected from back surface of PV module and solar radiation being transmitted through non packing area of module are utilized for heating water passing through the pipe in the collector. The collector is connected to the single slope solar still. The top of the solar still is covered by a transparent glass inclined at an angle of 30^0C with the horizontal . The inside surface of side walls and bottom are blackened for maximum absorption of solar radiation. The solar radiation falling on the outer surface of transparent glass after reflection and absorption is transmitted to water and basin liner where it gets absorbed.

The schematic of partially covered photovoltaic flat plate collector active solar distillation system is shown in fig. 1 (Singh et al, 2011).

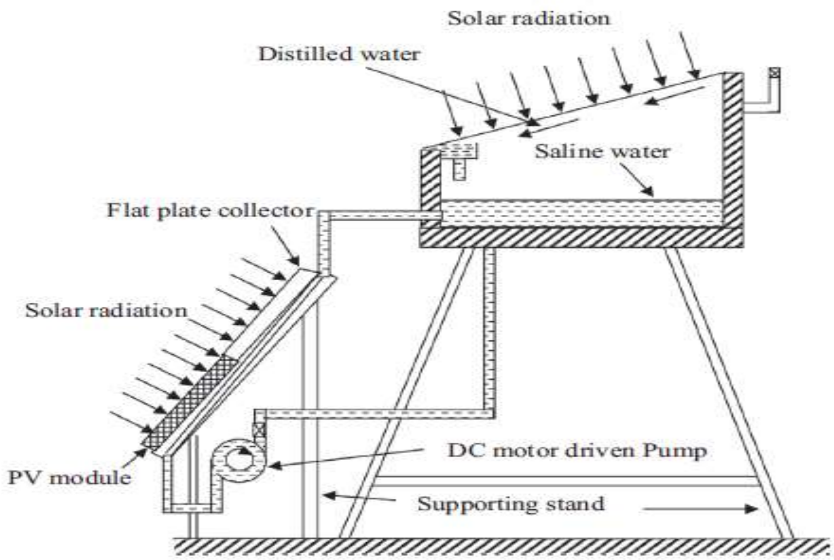

Fig. 1 View of partially covered photovoltaic flat plate collector active solar distillation system.

Solar water heater in single basin solar still

The proposed design aims to increase the water temperature in the basin without any additional cost or operational difficulties. The solar water heater is the best option for increasing the basin water temperature. The evacuated tube collector (ETC)-type solar water heater is more advantageous than the flat plate collector type due to its greater reduction in heat losses caused by the vacuum present in the tubes. Evacuated tube solar collectors have improved performance compared to the flat plate collectors, particularly for high temperature operations (Budihardjo, 2007). System operated with a hybrid nature and was capable of producing hot water and distilled water.

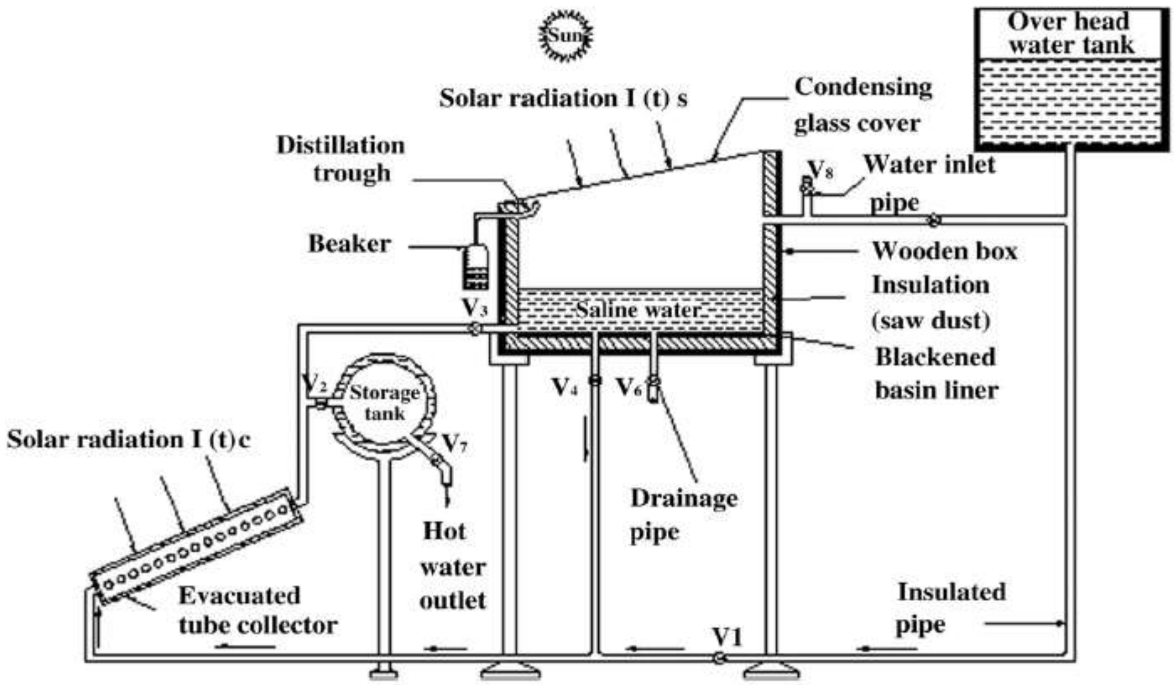

Fig 2. Solar distillation system integrated with solar water heater

Solar field as thermal source of the MED/TVC desalination system

The main components of aMED/TVC system are 'n' number of evaporation effects, the steam jet ejector, and the condenser as shown in Fig. 3. The steam jet ejector is composed of a steam nozzle, a suction chamber, a mixing nozzle, and a diffuser. As dry steam is entered into each effect from the last effect (from the TVC for the first effect), the seawater, which has been warmed up in the condenser, is sprayed on the evaporator tubes. One part of it becomes vapor and is flowed into the next effect evaporator tubes to be used as the heating source. The other part remains as a salty water and is directed to the next effects. Part of the vapor produced in the last effect is entrained by the steam ejector (Dev) and the remainder Df flows into the end condenser where it condenses by the cooling sea water stream. Motive steam from the external source (micro turbine wasted heat or Solar field) flows through the thermal vapor compressor and the portion of vapor that is entrained into the TVC is compressed. Depend on the flow direction of evaporating brine and heating steam, the MED systems are categorized into three configurations of forward feed, parallel feed and backward feed. It has been proven that the configuration of parallel feed configuration is most efficient as compared to the other two configuration (Wazeer, 2014). In the parallel feed configuration the evaporating brine and heating steam flows have the same direction. The preheated feed sea water is divided into the set of parallel streams to feed into each evaporation effect.

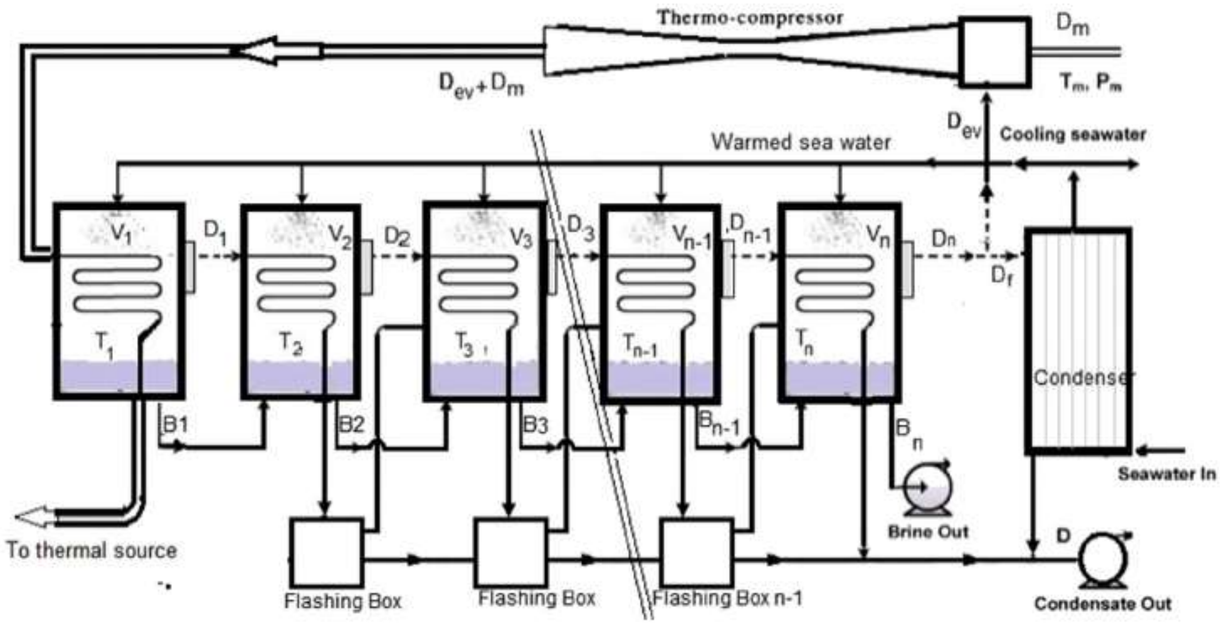

Fig 3. Multi effect desalination thermal vapour compression system- parallel feed

Hybrid sea water desalination system

Sea water distillation system is composed of following components :

- A multi-effect distillation plant with 14 cells in a vertical arrangement.
- A stationary CPC (Compound Parabolic Concentrator) solar collector field.
- A thermal storage system based on water.
- A double effect (LiBr-H_2O) absorption heat pump.
- A smoke-tube gas boiler.
- An advanced solar dryer for final treatment of the brine.

These subsystems are interconnected. The system operates with water as the heat transfer fluid, which is heated as it circulates through the solar collectors (McHarg, 2004). The solar energy is thus converted into thermal energy in the form of the sensible heat of the water, and is then stored in the tanks. Hot water from the storage system provides the MED plant with the required thermal energy. In absence of solar radiation, the gas boiler feeds the absorption heat pump, which is also fed with low temperature steam from the last MED plant effect , in order to heat the water coming from first effect from 63.3ºC up to 66.5ºC(Millow, 1996).

Hybrid RO-MED solar desalination system

The system takes advantage of high-efficiency, commercially available RO technology as well as high recovery MED technology (Kamal, 2005). From the perspective of water flows, the RO system takes brackish feed water, desalinates to the limiting recovery ratio, and sends the resulting brine to the MED system, where it is desalinated further. From the perspective of energy flows, the system is powered by a locally-sited CSP plant. The steam produced by the solar collector field runs a Rankine power cycle to produce electricity for the RO system and auxiliary components of the MED system (Zak, 2004). Turbine exhaust steam drives the MED process. A trough collector solar field collects the solar irradiation, as this method.

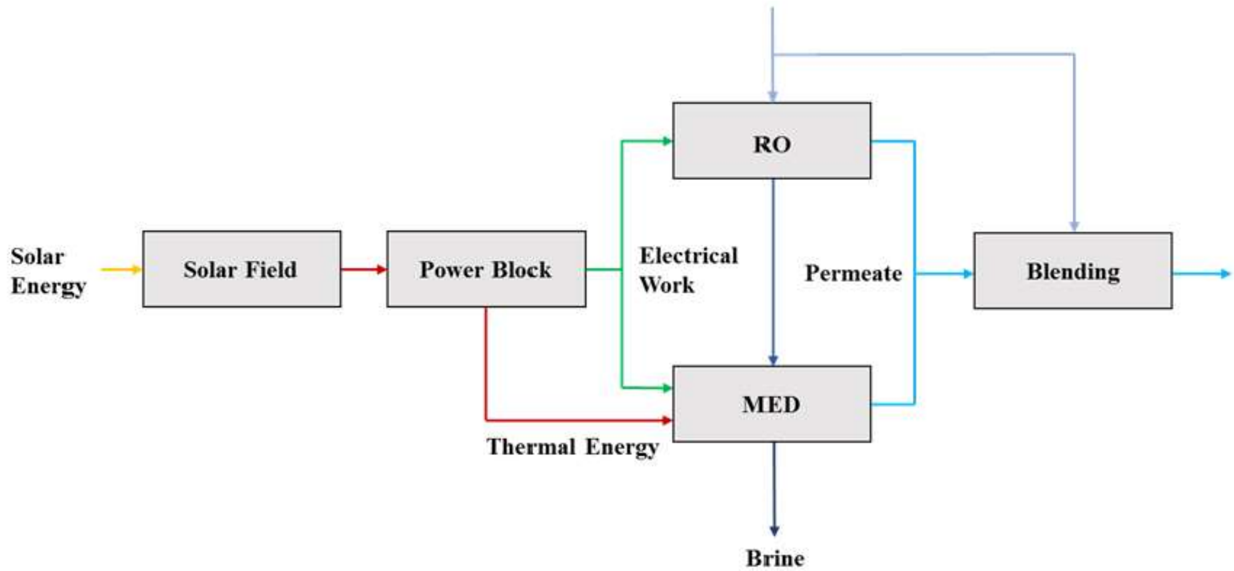

Fig 4. CSP powered hybrid RO-MED desalination system

Performance assessment of hybrid systems

A hybrid desalination system design for treating agricultural drainage water. Provided the additional pretreatment costs associated with operating the RO system at a specific recovery are less than the projected savings, the hybrid system is cost advantageous (Trieb, 2008). The multi effect thermal vapor compression (MED/TVC) desalination system with the Linear Fresnel (LF) solar field thermal energy source. A typicalMED/TVC systemwith hourly required thermal energy of 15.6 MWt and hourly water production rate of 375 m3/h (9000 m3/day) (Ameri and Askari, 2016).

When the solar still is coupled to solar water heater integrated with evacuated tubes then it increase the yield by 77 % (Sampathkumar, 2012). In the case of active solar still, thermal energy from outside is fed to the basin with an aim to increase the water temperature in basin so that rate of evaporation increases and ultimately higher yield is obtained. Energy can be fed to the basin in many ways such as PVT collector is one of the way (Singh, 2016).

CONCLUSION

It has also been observed that the hybrid system is self sustainable and it can meet potable water requirement as well as electricity requirement in case of PVT collectors. On the basis of energy and capital, a concentrated solar-powered hybrid RO/MED plant provides significant cost benefits over a concentrated solar-powered standalone MED system for treating agricultural runoff. Use of a renewable energy source, such as solar thermal energy, in the desalination process, improved MED process efficiency through incorporation of the absorption heat pump technology, and reduction of the environmental impact. Also found that the thermal efficiency of active solar still is lower than the passive solar still. The proposed systems will be more useful for rural applications, where the quality water is not suitable for drinking.

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