Membrane distillation
- Experience in field applications and potentials

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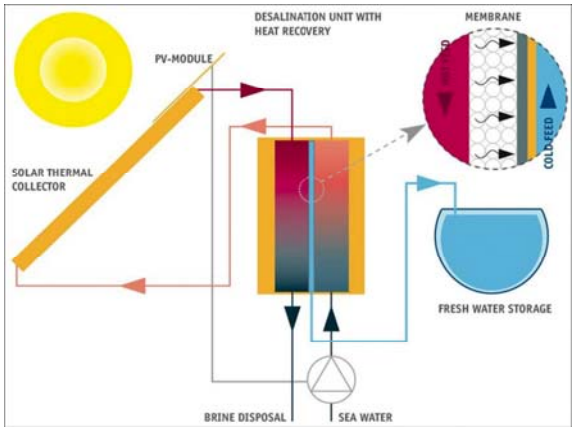
Clean water is a resource becoming more scarce as the demand and the social responsibility to provide it is increasing rapidly. SolarSpring GmbH (SSP) is a developer of clean-energy water systems. Our solutions desalinate and treat seawater and non-potable water using solar energy or waste heat. These clean energy sources are used to power technologies such as membrane distillation, ultrafiltration, UV disinfection and more. Our expertise is in the design and integration of water treatment systems that operate on low or intermittent energy sources.

With photovoltaic ultra filtration, reverse osmosis and UV disinfection systems have been realized. Solar thermal collectors and wasted heat are ideal for the application of membrane distillation (MD). Today SolarSpring employees are pioneers in the operation of solar membrane distillation systems. SolarSpring was founded in 2009 as a spin off of the Fraunhofer ISE and can revert to the long term field experience with solar driven MD-systems. Around the world 15 small scale systems (Orxy) have been installed and are in operation. Also several modular MD systems with a capacity up to 5 m³/d fresh water have been installed and are in operation. All systems are either 100% solar driven for an autonomous operation or combined with waste heat. Up to now, systems have been installed in countries from Mexico to the Middle East, Africa and Australia.



Schematic of the Oryx 150 [5]

Oryx 150 in Mexico

Long term experience with solar membrane distillation

One of the first solar driven membrane distillation systems (Oryx150) has been installed on Gran Canary for field testing and demonstration in 2004. This took place in the framework of the MEMDIS project and the operation continued in the MEDIRAS project [1] in cooperation and at the test facilities of the Instituto Tecnologico de Canarias (ITC). The collected data from this small scale system (Oryx150) have recently been analyzed and will be published soon [2]. The experience made with more than 20 installed membrane distillation systems (single module Oryx and multi-module systems with up to 12 MD-modules) show that the advantages of that technology can prevail.

· Standalone system design for remote off-grid locations

· Consistent water quality

· Suitable for many feed water sources, across many salinities

· Low fouling, long term operation

· Automatic operation with no operator needed

· Only simple pre-treatment needed

· Direct operation with intermittent energy supply

Oryx 150 in Tunisia

Even the downside of desalination, its high energy consumption can be tackled with high efficient solar collectors and reduction of heat losses within the system technology, waste heat usage and further improvement of the internal heat recovery. During system operation the distillate output could be increased through improvement of control algorithms. In applications and with limited raw water supply a feed water recirculation is necessary to increase the recovery ratio. With this system configuration, it could be observed, that the specific energy consumption rises with the recovery ratio, due to the negative effect of the higher salinities. Also a cooling of the brine becomes necessary so the temperature difference can be maintained. Aside of the general operational data, mechanical stability, fouling, scaling, membrane life span where evaluated.

The long term field tests have also shown that the selectively of the membrane can be kept up 5 years. The quality of the distillate output is generally independent from feed salinity and has been kept in the range 20 – 200 µS/cm, even though in the laboratory the values achieved are far lower. The membrane itself is rarely the reason for module failure but rather constructional difficulties or operational malfunctions like overheating or over pressure. The pressure is generally monitored also to be able to make conclusions about scaling in system components like heat exchanger. As expected, it could be shown that scaling is no problem on the membrane, but can occur depending on the raw water composition in the solar collectors and on seed crystals in the spacer structure. Therefore cleaning intervals might be necessary and vary from 0 to 4 times a year depending on raw water sources. They can be easily determined by the increase of pressure loss. Other measures to increase the product water quality have also been taken end evaluated. To improve the taste and the quality of the produced drinking water a re-mineralization of the distillate was implemented. The distillate is leaving the MD system with close to no minerals left and a pH- value between 5,5 and 6,5. After the proper re-mineralization the water has a neutral character and with the intake of mainly Calcium and Magnesium a conductivity between 100 and 200 µS/cm. With the addition of an integrated UV- disinfection, storage and distribution or tapping-system a save water supply can be realized even if it has to be stored over a long time period.

Potentials of membrane distillation

The membrane distillation technology has many potential applications that have to be evaluated more carefully and where further research is needed. MD can be used as separation process not only in water treatment but also food processing, chemical industry and the agricultural sector.

Production of ultrapure water with a maximum conductivity of 1 µS/cm

SolarSpring supplied a MD system for the production of ultra pure water made of effluent from a waste water treatment plant (WWTP). Under laboratory conditions it was possible to produce water with a conductivity around 0.19 µS/cm [6]. This water will be suited to operate an electrolyzer unit that will help to close the external energy demand of the WWTP by using internal resources. One of the main levers to optimize the waste water treatment process is to inject compressed oxygen into the biological reactors. The oxygen is to be generated via electrolysis driven by renewable energies using the treated waste water as raw material. MD is favored for this task because compared to e.g. reverse osmoses the membrane it thought to be less prone to fouling and a difficult pretreatment should not be necessary.

The effluent of the WWTP was tested beforehand if it is suitable for the MD-technology. Waste water can contain a great variety of substances that influence the MD-process. Special attention has to be directed at tensides and volatile substances like Ammonia. Tensides can lower the hydrophobicity of the membrane and degrade it's selectively. Volatile substances pass through the membrane with the water vapor even at lower vapor pressure differences. For water purification this poses a difficulty that was further analyzed, but for other industrial applications this can be a valuable application. The removal of Ammonia to recycle valuable nutrients or just to improve the quality of effluents is just one of the great potential applications of MD. Looking at many volatile substances such as Chloroform, Toluene, Acetone, Phenol, Ethanol and VOC (volatile chlorinated hydrocarbons), membrane distillation could be used for medium separation in a great variety of processes.

For the production of ultrapure water a volatile substances like ammonia poses a great challenge. With the pilot MD-system build by SSP for the generation of ultra-pure water the influence of the ph-value changes on the ammonium/ammoniac equilibrium and the increase of retention potential was tested. With this analysis requirements on feed water quality for membrane distillation systems could be determined to enable the design of appropriate WWTP water output treatment.

Production of highly concentrated salt water

SSP is involved in an EU – Project called Reapower [4]. REAPower targets an innovative concept based on the reverse electrodialysis (RE) technology. This technology consists of the extraction of the "osmotic energy" from two salt solutions showing a large difference in salt concentration, what is called salinity gradient power (SGP). The objective of REAPower is to prove that the concept of electricity production through Salinity Gradient Power- Reverse Electrodialysis (SGP-RE) using brine and sea or brackish water is feasible and to develop the necessary materials, components and processes. The SGP-RE is a clean, renewable energy with large global potential since the electricity is produced simply from supplies of water with different salt concentrations. Extensive testing of the laboratory stack will be performed in order to evaluate the effect of the real feed composition on the process. The effect of hydraulic conditions on the power density will be further evaluated on a larger laboratory stack. This will be also used to test the combination of this technology with the membrane distillation concept and the pre-treatment requirements of different brine inputs. Therefore SolarSpring will develop a MD-system that can generate highly concentrated salt water. Laboratory tests have been made with the current system configurations that evaluate the influence of salt concentration but also saltwater compositions on the distillation process.

Additional potentials of these analyses can be seen looking at MD as a technology to complement other desalination systems like reverse osmosis, electro dialyze, etc. Since MD can handle higher salinity as other desalination processes it poses an option to increase recovery ratios or decrease discharge volumes even for (close to) zero liquid discharge applications. Further experiments are on the way that will evaluate different MD-module configurations.

References

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