Solar Thermal Seawater Distillation Activities at the Plataforma Solar de Almería: Increasing the Thermo-Economic Process Efficiency

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Fresh water scarcity is a pressing problem that progressively affects more and more regions on the planet due to the continuous increase in world population, changes in life style and the increasing contamination of existing natural freshwater resources. Industrial seawater desalination appears to be one of the best options to palliate this problem because more than 70% of the world's population lives within 70 km of seas or oceans [1]. At the end of 2001, some 24,000,000 m^3/day of desalination capacity was in operation [2], however, energy consumption by the process is high and to lower costs, two different approaches should be used: optimization and minimization of energy consumption, and/or the use of renewable energies [3]. Due to the usual coincidence in many locations of fresh water shortage, abundant seawater resources and high insolation levels, solar water desalination becomes feasible and very attractive [4]. For high fresh water demands, application of indirect solar thermal desalination, which consists of coupling a solar collector field to a conventional thermal distillation plant, is required [5]. Distillation methods used in indirect solar desalination are multi-stage flash (MSF) and multi-effect distillation (MED). The MSF process has long been the worldwide mainstay for large-scale water production, especially in the Middle East, but its position is now being challenged by recent developments in MED technology as a number of new, larger-capacity MED plants have been built for a lower cost than the equivalent-capacity high-efficiency MSF plants [6].

Since the end of the eighties, the Plataforma Solar de Almería (PSA) has been carrying out important research in the field of indirect solar desalination. The Solar Thermal Desalination (STD) Project [5], carried out from 1988 to 1994, had two main objectives: i) to study the technical and financial feasibility of this industrial application of solar energy, and ii) to optimize the solar thermal desalination system implemented by introducing and evaluating improvements minimizing electrical and thermal energy consumption to make it more reliable and competitive with conventional desalination systems. The solar desalination system implemented at the PSA was composed of: i) A 14-cell vertically-stacked MED plant (72 m^3/day), ii) A 114 m^3 thermocline thermal oil storage tank and iii) A one-axis tracking parabolic-trough solar collector field. The system employed synthetic oil as the heat transfer and storage medium that was heated as it circulated through the solar collectors. The solar energy was thus converted into thermal energy in a form (low-pressure steam at 70ºC) suitable for use by the desalination plant. With this configuration, a performance ratio (kg of distillate per 2,300 kJ heat input) of 10 was obtained. With the goal of improving that value, two procedures for recovering heat in the MED unit were studied, thermocompressors and absorption heat pumps. A prototype double-effect absorption (LiBr-H_2O) heat pump (DEAHP) was built and installed in the MED plant in order to recover the latent heat of the steam produced in the last effect. This configuration increased the performance ratio to 20. Although the technical feasibility of the system was demonstrated, its economics remained far from those of conventional desalination technologies.

The AQUASOL Project

Research activities in solar desalination at the PSA have recently been boosted by the startup in 2002 of a new European project called AQUASOL, having three main innovations: i) The solar field is based on new static CPC-type (Compound Parabolic Concentrator) solar collectors designed to supply medium temperature heat (60ºC-90ºC), ii) Development of a new double-effect absorption (LiBr-H_2O) heat pump, and iii) Reduction of process discharge to zero by recovering the salt from the brine in an accelerated process using advanced passive solar dryer techniques.

In the AQUASOL configuration proposed (see figure), water is the working fluid that transfers the thermal energy supplied by the solar field to the storage tank. A gas-fired backup system is necessary to guarantee minimum operating conditions (DEAHP requires steam at 180ºC) and permit 24-hour MED plant operation (to reduce the impact of capital costs). Although the system can operate in both solar-only mode and fossil-only mode, system efficiencies are different because the heat pump cannot operate with the contribution of the solar field alone. A third hybrid operation mode (solar-gas) would also be possible with the absorption heat pump operating at partial load, thus maximizing use of the solar resource. Plant configuration allows for multiple possibilities that can easily be adapted to the socio-economic circumstances of the location where the seawater desalination plant is to be installed.

AQUASOL developments are expected to reduce the overall system investment cost as well as improve energy efficiency and process economics, making it competitive with conventional desalination techniques, even leaving aside environmental considerations.

References

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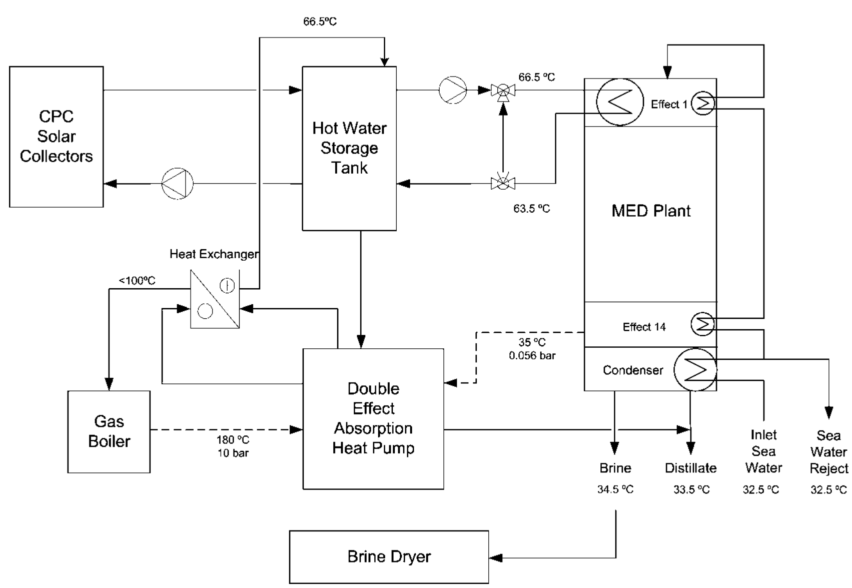

Figure Configuration proposed for AQUASOL Plant