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Technical and Economic Analysis for A MED System and Hybrid MED-RO Desalination in CHP Plant

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Effective integration of membrane/thermal desalination and power technology can improve the performance of thermal desalination and reduce the cost of desalted water. In this paper two study cases with different configuration desalination processes are considered and compared. This comparison is performed using THERMOFLEX® software. The first case is a 25 MW gas turbine engine that is coupled with a MED_TVC thermal desalination plant and for the second one a hybrid desalination system is coupled with the mentioned gas turbine. For the hybrid process proposed to feed the MED unit with brine discharge of SWRO system. The operation of the hybrid configuration was simulated, the technical and economical results calculated and compared with those that could be achieved by an equivalent MED-TVC system. The main target of this analysis is to improve performance of MED-TVC desalination process by changing its feed water flow pressure, as well as to determine the changes in unit product cost of the desalinated water compared with MED-TVC product cost.

1. Introduction

The interest of cogeneration is to increase the overall efficiency of producing electricity and heat with respect to both processes being done independently. In previous works, the application of desalination process in dual purpose plants has been discussed. Various aspects of seawater desalination economics and optimized configuration selection based on energy, capital and operating costs have been studied by Andrianne et al. (2002).

Sayyaad et al. (2010) have been performed thermoeconomic optimization of a multi effect distillation (MED) desalination system with thermal vapor compressor (TVC) to minimize the cost of the system product. The GOR value in MED-TVC (*Figure 1*) system is greater than MED system by result of decreasing in steam consumption with consideration of TVC in the system, which was recently confirmed (Kamali, 2007).

In the field of thermoeconomic analysis of coupling Hybrid MED/SWRO desalination plant with single gas turbine power plant, a broad investigation has not been performed yet. In this paper a cogeneration plant located in the south of IRAN is proposed. The existing plant is based on a UGT25000 gas turbine simple cycle and a desalination plant. Multi effect distillation coupling with a TVC system is used technology in proposed plant. The performance of mentioned plant using a thermoeconomic analysis was previously conducted by Ansari et al. (2010).

During winter season, demand for power and water is decreased for mentioned plant, but the key issue is that the relative decreasing power demand is higher compared to

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water demand. A good opportunity is there to install electrical driven desalination process like RO to complement with existing power and thermal desalination plant, creating integrated hybrid desalination system.

In this research two study cases have been analyzed utilizing THERMOFLEX ®, a software obtained under license from Thermoflow, Inc. to simulate the design of power/seawater desalination plants. In the first case the existing plant based on gas turbine coupling with MED-TVC (Figure 1) water desalination has been simulated. According to demand fluctuation/degradation during winter season, the second case by coupling a RO plant to existing thermal desalination system has been supposed in order to optimize the MED plant operation. It is assumed to feed the MED unit with brine coming from the RO (Figure 1), which still has a pressure of 3–4 bar (Rensonnet 2007).

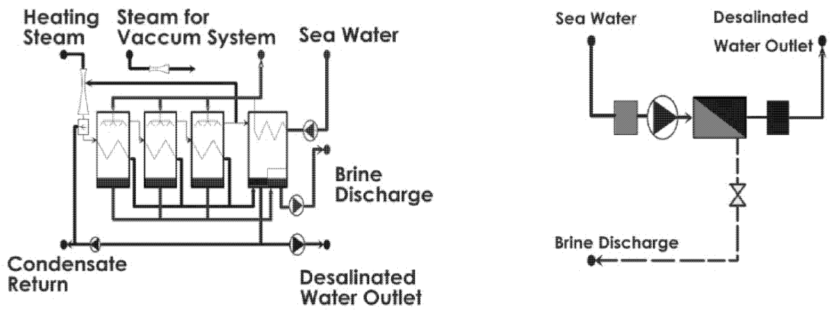

Figure 1: MED-TVC and reverse osmosis (RO) system

2. Simulation

In this paper an existing power and water desalination plant has been analyzed. For the mentioned plant, for the first case assumed that a 10000 m^3/day MED-TVC desalination system powered by waste heat from a UGT-25000 gas turbine. The mentioned plant is modeled by THERMOFLEX ®. In this thermodynamic modeling optimized parameters have been developed for the system.

Table 1: Specifications of power plant

Power Cycle/ HRSG	Value
Inlet air temperature (°C)	25
Turbine inlet temperature (°C)	1100
Net power output (MW)	22.3
Gross LHV efficiency (%)	34
Exhaust temperature of HRSG (°C)	133
Inlet water temperature (°C)	20
HRSG IP Pressure (kPa)	1200

According to fluctuation of the power and water demand a modified dual purpose power/water plant has been designed on the basis of hybrid concept. The MED and RO designs are to be optimized in such a way to take full advantage of pressure energy of the RO brine discharge. In purposed case, an electrically driven RO system where apply to power water co-generation plant (Fig. 2). For this case sea water RO reject brine was used as makeup to the MED-TVC plant distiller. The MED-TVC was monitored and its operation results were analyzed. The optimized parameter of the mentioned cases is presented in Table 1 and Table 2.

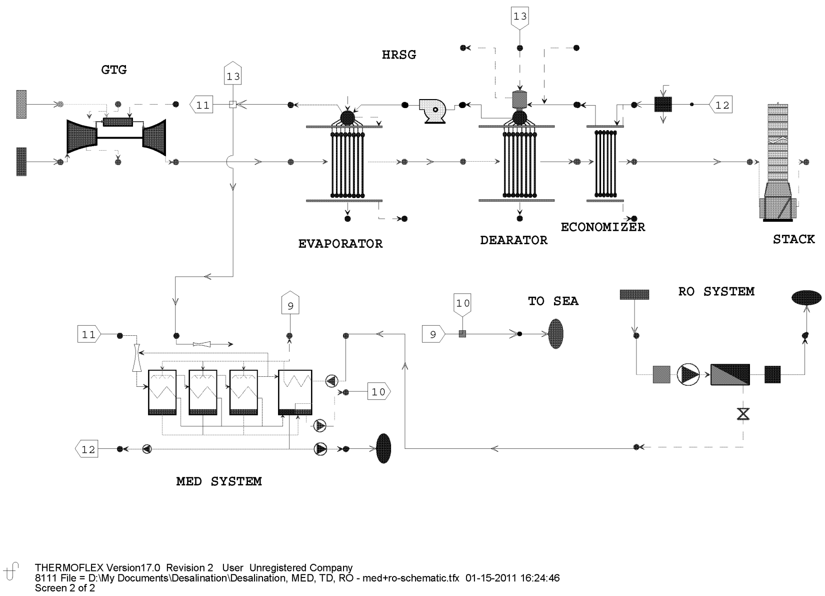

Figure 2: Modified SWRO/MED desalination dual purpose plant

Table 2: Specifications of two cases

	Case 1	Case 2
Capacity of MED (t/day)	9607	9550
Temperature of the brine inlet (°C)	20	22
Temperature of ambient (°C)	25	25
Salt composition of the brine inlet (%)	0.034	0.049
Salt composition of the brine outlet (%)	0.052	0.062
Number of effects	6	6
Temperature of the vapor to the first effect (°C)	70	70
Temperature of the last effect (°C)	40	40
Motive steam pressure (kPa)	1200	1200
Motive steam flow (t/h)	42.59	42.59
Specific power for the electrical instrument kWh/m^3	0.99	0.65
Total Steam consumption (t/h)	43.44	43.44
Total brine outlet (t/h)	798	793
Coolant sea water(reject) (t/h)	376	676
Total sea water inlet (t/h)	1573	1866
Gain output ratio	9.3	9.3

3. Economic Model

The economic model takes into account the cost of the components, including amortization and maintenance, and the cost of fuel consumption. In order to define a cost function, which depends on the optimization parameters of interest, component costs have to be expressed as functions of thermodynamic variables (Mabrouk et al. 2007 and El-Sayed, 2001). These relationships can be obtained by statistical correlations between costs and the main thermodynamic parameters of the component performed on the real data series.
In the evaluation and cost optimization of an energy conversion system, it is required to compare the annual values of capital-related charges (carrying charges), fuel costs, and the operating and maintenance expenditures. These cost components may vary significantly within the system economic life. Therefore, levelized annual values for all cost components should be used in the evaluation and cost optimization (Bejan 1996).
For economic evaluation the Total Revenue Requirement (TRR) method (which is based on procedures adopted by the Electric Power Research Institute (EPRI 1993) has been used.

Table 3: Economic constants and assumptions for two cases

Parameters	Value
Unit cost of electricity ($/kWh)	.07
Unit cost of steam ($/t)[1]	1.47
Useful life (y)	25
Interest rate	.10

This method calculates all the costs associated with a project, including a minimum required return on investment. Based on the estimated total capital investment and assumptions for economic, financial, operating, and market input parameters, the total revenue requirement is calculated on a year-by-year basis. Finally, the non-uniform annual monetary values associated with the investment, operating (excluding fuel), maintenance, and the fuel costs of the system being analyzed are levelized; that is, they are converted to an equivalent series of constant payments (Tsatsaronis et al. 2002).
Table 3 represents the economical constant, parameters and assumptions that are used in economic analysis of this work.

4. Result and Discussion

The performance analysis of a co-generation plant has been considered and two desalination configurations evaluated. A summary of results are listed in Table 2. The cogeneration system, consisting of a gas-turbine, and a HRSG together with a MED-RO desalination process, has been selected and integrated to construct the modified CHP desalination plant. Applying thermodynamic analysis on the proposed desalination plant shows that in the hybrid configuration with MED fed by the RO brine discharge; by

[1] HRSG capital and O&M cost are levelized during project lifecycle

recovery the energy of rejected brine a significant decrease in the specific electrical consumption of nearly 36 % was achieved.

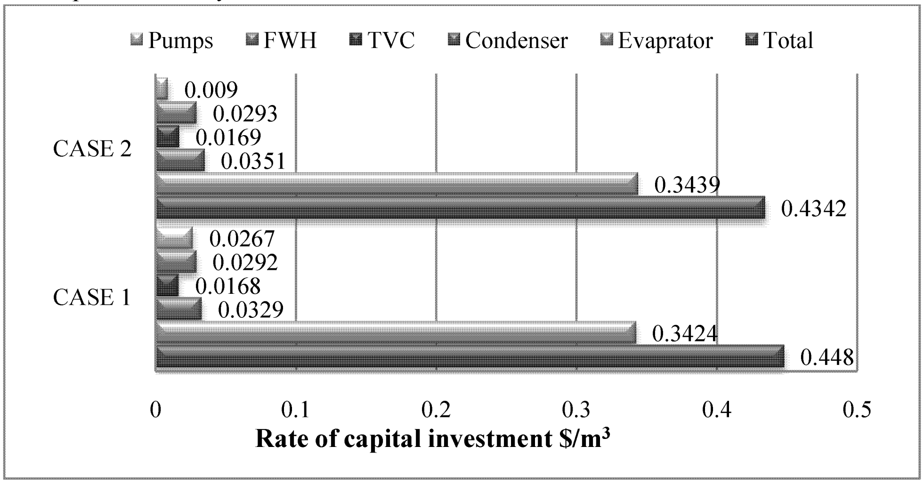

Figure 3: Variation of capital investment rate and PEC for each part of system

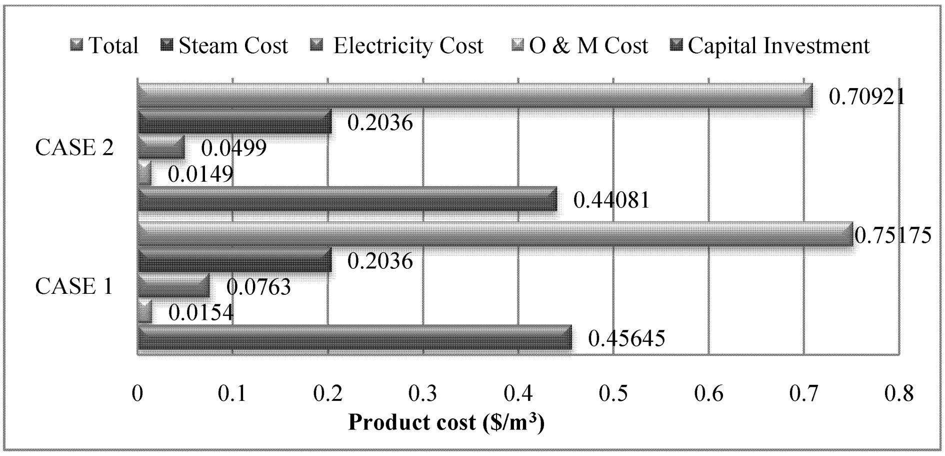

Figure 4: Variation of product cost and its components

Also an economic feasibility assessment has been conducted for simple and hybrid configuration. Table 3 shows the assumed data for economic analysis. It shows that with an expected lifetime of 25 years, an annual discount rate of 10 %, the desalinated water production cost for the second case would have a reduction of 6 %, in comparison with the first one.

As shown in Figure 3, due to decreasing in pumps capital cost, rate of capital investment has been decreased.

Figure 4 presents the weight of components in total product cost. It is indicative of the fact that, reduction in electrical cost and capital investment leads to decrease in unit product cost.

5. Conclusion

The present study implements, technical and economic evaluation for two configurations of dual purpose CHP system has been carried out.
A hybrid configuration with MED feed by the RO brine discharge and a MED-TVC (overall desalinated water productions are about 10,000 m^3/day), have been studied. The operation of these proposed systems was simulated, the economical and energetic result calculated and compared with each other.
The predicted behaviour of proposed integrated CHP and hybrid desalination plant has demonstrated that highly effective energy utilization can be achieved.
According to results obtained in this paper, from an energy efficiency and final plant product cost point of view, hybrid configuration desalination system coupled with a power plant is more interesting than a standalone MED system.

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