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Optimal design of a hybrid RO/MSF desalination system in a non-OPEC country

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Abstract

The hybrid process of seawater desalting couples the reverse osmosis with the multi-stage flash process. The hybrid process is usually planned to improve the performance of MSF and reduce the cost of desalted water. Most of the studies on these plants refer to the parameters (both technical and economical) that have been obtained in the countries where desalination processes are in common use. In general, these are also the countries where low cost energy is more available. That is why these results can hardly be compared to those of countries having limited energy resources. Our aim in this paper is to compare the costs to be calculated for a hybrid desalination system in the two situations cited. Our objective is to study the system in order to calculate the minimum water production cost as a function of the main parameters of the MSF section. Calculations are carried out using two different values of the energy cost (fuel and electric energy) as well as for two different flow rates of the desalted water produced by the plant. Therefore, our calculations allow us to compare the production cost of desalinated water in a country with large amounts of energy resources (for example an Opec country) with that of a non-Opec country.

Keywords: Desalination; Hybrid process; Cost analysis; non-Opec countries

1. Introduction

The amount of fresh water resources in Mediterranean countries is continuously decreasing due to increasing demand and low rainfall. As an example, the annual average rainfall on our island (Sardinia) has been approximately 500 mm in the last 30 years, while it was about 750 mm during the previous 50 years. Moreover, strong variations of annual rainfall have been registered in the last few years. One consequence of this is that the management systems of the water resources have been improved. At the same time, several studies have begun to investigate other non-conventional sources, like re-use and desalination [1]. This study of a desalination process is a small part of the wider area of work currently

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being carried out in our region on the feasibility of these options.

An economic analysis of industrial desalination processes shows that the most important factors influencing water cost include both energy cost and capital costs. Therefore, these two parameters should be specially modified in order to reduce the cost of the desalinated water.

The energy costs of desalination may be reduced by means of the following two options: (1) the use of non-conventional energy sources and (2) the minimization of energy consumption and economic optimisation.

Many researchers have investigated the use of non-conventional sources (i.e. renewable sources) for desalination processes. In fact, the many energy sources now available at a lower price, such as solar, wind, geothermic and energy derived from combustion of refuse, are employed to produce thermal and electric energy. These same sources could also be utilised for desalination [2]. However, at least up to now, these systems have not been suitable for use in large scale plants, both for technical and economic reasons. Therefore, in this work we refer to the second option, and consider a plant where a traditional fossil fuel is used (specifically, a low sulphur fuel oil, LSFO) calculating the values of the process parameters that minimise the total water cost.

The system studied here is that of a dual-purpose plant, where the desalination process is obtained through a hybrid process of multi-stage flash (MSF) and reverse osmosis (RO) [3,4]. It is important to point out that the economic impact of these plants is quite different if they are installed in a country where low cost energy is available rather than in a country lacking in locally available energy resources. In the first case, the cost of energy will clearly be lower and large amounts of waste heat are often available for desalination. When energy resources are limited or not available as is the case in Italy (except for a few cases relative to industrial use) only high quality fuels such as LSFO can be used for desalination. Such fuels have high value and a high price. Most cost analysis studies on desalination equipment concern places where low cost energy is available. However, the results obtained in such cases cannot be applied to fuel importing countries. Yet desalination plants exist in these countries too and some of these plants are designed for civil use, so the availability of waste heat streams is unlikely. With these considerations in mind, this paper carries out a cost analysis that will enable us to compare the costs in the two locations cited.

As regards the plant configuration, the addition of a RO plant to be operated in parallel with a MSF plant while sharing a common intake facility is an option worth considering for future expansion in desalinated water production. A dual-purpose plant, coupling a distillation and a RO plant offers high flexibility in the cogeneration of desalinated water and electricity, because the RO plant can satisfy water demand when the electric energy demand is low [3,4].

The impact of rising fuel prices has increased the use of RO technologies since energy consumption is smaller in comparison to that of all the conventional desalination technologies. This couples with modern membrane technology, which reduces pre-treatment costs.

In this paper we model a hybrid desalination plant. The fresh water demand of a city such as Cagliari (Sardinia, Italy) is taken as a basis for calculations which are made assuming two different rates of desalinated water production: 100,000 and 30,000 m^3/d. The first amount is considered to satisfy the total demand for fresh water in a city like Cagliari, while the second clearly fulfils it only partially.

The calculations for the two scenarios are carried out using two different values for energy costs. A low value of 0.02 €/kg [5] is assumed to indicate the fuel cost in an energy exporting country while we assume a higher value of 0.2 €/kg for a fuel importing country.