

Analysis of integrated co-generative schemes including MSF, RO and power generating systems (present value of expenses and “levelised” cost of water)

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Abstract

The proposed study provides an analysis of an integrated co-generative scheme including the following subsystems: (1) gas turbine and unfired heat recovery steam generator, (2) auxiliary boiler, (3) multistage flash (MSF) and (4) reverse osmosis (RO). It contains a comparison of the integrated system with the reference scheme. A comparison of alternatives was based on the present values (PV) of expenses over the economic life of capital and “levelized” cost of water. The analysis was based on the following assumptions: (1) depreciation period is equal to the period of bank credit; (2) zero year is the base year of the project; (3) the discount factor is dependent upon the nominal interest rate and retail price index, (4) cost of primary fuel ranges from 1 to 4 \$/GJ, (5) assumed carbon tax varies from 0 to \$50 per tonne of emitted carbon. Based upon calculated results, the study confirmed the statement that RO can successfully coexist with MSF. Hybridisation of thermally- and electrically-driven processes can provide the following advantages: (1) a decrease of PV of expenses, (2) decrease of specific capital and energy consumption; (3) decrease of the level of carbon tax (owing to a drop of allocated CO₂ emissions); (4) decrease of “levelized” cost of water. Incorporation of RO into existing co-generative systems decreases its sensitivity and, in turn, commercial risk of the system to fluctuation of the following factors: (1) nominal interest rate (2) cost of primary fuel and (3) rate of carbon tax. The array of calculated data and projections is attached.

Keywords: Reverse osmosis; Hybrid desalination; Co-generation; Economic analysis; Cost of water; Sustainable development

1. Introduction and objective of the study

A new generation of integrated schemes including power generation, MSF and RO

desalination is becoming an attractive alternative to conventional systems. Incorporation of RO into existing co-generation plants can provide economic, environmental and operational advantages over conventional dual- and mono-purpose

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plants, namely: (1) the ability to diversify range of the power-to-water ratio that is essential for regions where demand pattern is characterised by a low level of its value, e.g., Abu-Dhabi; (2) the possibility of using a seasonal surplus of unutilized power; (3) the ability to decrease specific fuel consumption since RO is less energy-consuming than MSF; and (4) the ability to decrease specific CO₂ emissions. The concept of integration of thermal- and electrically-driven desalination was scrutinised by many authors [1–12]. Some authors state that RO can successfully coexist with MSF rather than a process that should replace it.

A comparative analysis of the systems with a multi-layer hierarchy and load-dependent characteristics requires a systemic approach which is based on different groups of performance indicators, namely: ecological, technological and economic ones [13]. The evaluation procedure can be subdivided into two stages: (a) evaluation of indicators for the base year and (b) evaluation of long-term projections of the indicator behaviour. Previous studies [14,15] were focused on evaluation of load-dependent indicators for the base year of the project where the following indicators were used: (a) water cost; (b) cost of electricity; (c) cost of low-grade heat; (d) specific CO₂ emissions, and (e) cost of CO₂ emissions through an imposed carbon tax.

The current analysis is based on an estimation of long-term projections. Here it is the present value (PV) of expenses and “levelised” cost of water that were assumed to be the profitability measure of alternatives. The PV concept implies that all expenses are supposed to be placed on a comparable basis (converted to base year). Interest to long-term projections of PV depends on the type of property. Behaviour of long-term projections is strongly influenced by type of ownership and economic legislation. For plants governed by federal law and being under the jurisdiction of state commissions or other

regulatory bodies, long-term cost projections are not so significant as opposed to cases with privatised plants or investor-owned assets. A long-term-based analysis was used by Leutner for evaluation of a dual-purpose plant [16]. An analysis based on long-term cost projections is essential for investor-owned plants. The current tendency towards privatisation has stimulated interest in the analysis of long-term behaviour of economic indicators.

Within the context of the outlined problems, the proposed study provides a systemic approach to evaluating triple hybrid systems. It is focused on a comparison of profitability of triple hybrids with a reference scheme. The triple hybrid (or integrated scheme) includes the following systems: (1) GT and unfired HRSG, (2) AB, (3) MSF and (4) RO, while the reference scheme contains only three systems: (1) GT, unfired HRSG, (2) AB and (3) MSF. RO is not included in the reference scheme.

Integrated schemes and load-dependent indicators for the base year have been analyzed [14,15]. The structure of annual expenses includes the following groups: (a) fixed charges for capital recovery; (b) O&M expenses; (c) energy expenses and (d) a carbon tax. The current tendency towards reconfiguration of the system of taxation, implementation of ecological taxes and policy of emission trading makes essential a quantification of any environmental damage in the cost-benefit analysis. The importance of the issue was stressed by Riordan and others [17–20].

In this study an attempt to account for CO₂ emissions through the imposition of a carbon tax was made. The carbon tax was considered as an expense and allocated into the cost of the produced thermal and electrical energy. Its discounted value was included in the cumulative PV of expenses. The influence of load on cost of electricity and low-grade heat is considered as well.

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