Options for improving attractiveness of renewable energy powered desalination

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Abstract: With an advancement of technology and rampant growth in installed desalination capacity in last decade, it has become imperative to analyze the energy required for the same and associated greenhouse gas emission. With an increasing concern over the green house gas emission, the attention is being paid to the area of renewable energy. More recently, the thrust is being given to renewable energy driven desalination plants, especially powered by solar energy. Solar powered desalination is also being considered as an option for remote and sparsely populated locations, not connected with electrical grid. The present paper discusses the concept of overall energy efficiency.

Life cycle green house gas emission of a coal based thermal power plant is 1001 g CO_2/ KWH whereas the same for solar PV is 46 g CO_2/KWH [1]. Considering the specific power consumption of 4 KWH per cubic meter of water produced and approximately 10% of global desalination capacity being converted to solar powered desalination i.e. 7840 million liters per day [2], close to 29,950 tons of CO_2 will be saved from getting emitted in world's environment, each day. This justifies the research on renewable energy powered desalination.

Renewable energy powered desalination seems very attractive on prima facie; however, the high capital cost of renewable energy generation and lower reliability in terms of consistency are the major impediments in its implementation. To make the renewable energy powered desalination attractive, the energy requirement for desalination should be minimized and the options of using low grade energy i.e. waste heat can be explored.

The options for reducing the power consumption by reverse osmosis have been explored world over. There has been thrust on developing the technology of nano-composite membrane that reduces the energy consumption by ca. 20% by imparting nano-material in the barrier layer of TFC membrane. There has also been thrust in perfecting the technology of recovering the energy from the concentrate stream by using different types of energy recovery devices e.g. pressure exchangers. However, there is a little focus on very easy option of reducing the energy consumption by increasing the feed water temperature. The

feed water temperature can be increased by any low grade heat source. Increased temperature of feed water improves the product water flow rate to a substantial extent with slight decline membrane selectivity. This will be particularly useful for brackish water reverse osmosis where the re-mineralization of product water can be avoided by slightly lower selectivity of the membrane and improved flow rate results in decrease of energy consumption to a greater extent. The synergy can be achieved when the high flux membrane is used with high temperature feed water to significantly reduce the power consumption.

The specific energy consumption can be reduced by the following methods from the first principle. [3]

1. Increasing $\Upsilon = A_{total} Lp \Delta\pi_o / Q_f$ ……..(1)
2. Increasing number of stages
3. Using energy recovery device

$Lp = C_{LP} \bullet \exp(-Ea^{LP}/RT)$ [4] …….. (2)
Where Lp = hydraulic permeability
C_{LP} = Constant
Ea^{LP} = Activation energy represents the per mole difference in enthalpy of a molecule which is necessary to overcome the transport barriers during its passage across the membrane
T = Temperature

Substituting (2) in (1)

$$\Upsilon = A_{total}\, C_{LP} \bullet \exp(-Ea^{LP}/RT)\, \Delta\pi_o / Q_f \text{ …….. (3)}$$

Therefore, T has to be maximized for maximizing Υ. Hydraulic permeability increases at higher temperature which in turn results in improved Υ. Similarly, increasing number of stages and using energy recovery devices will also reduce the specific energy consumption for reverse osmosis.

In this way, the present paper analyzes the options for reducing specific energy consumption to make renewable energy powered desalination attractive and also demonstrates the synergy created by combining various options.

References for abstract:

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