Fuel Cell Operated Reverse Osmosis Desalination System

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Presentation Outline

1. Introduction.
2. What is a Fuel Cell.
3. Phosphoric Acid Fuel Cell (PAFC).
4. Cell Reactions.
5. Reverse Osmosis (RO) Desalting Plant.
6. Economy of Owing and Operating PAFC.
7. Conclusions.

1. Introduction

- The demands for both electric power and desalted water are continuously increasing.
- Very limited natural water resource.
- Desalination is the only available water resource to secure the required desalted water.
- This work discusses the feasibility of using a fuel cell to operate a reverse osmosis RO desalting plant.

2. What Is a Fuel Cell CF?

- Fuel Cells are similar to batteries in that they have electrodes to pick up and release electrons into the circuit and an electrolyte that conducts ions.
- Unlike batteries however, chemical reactants are continuously fed into the cell from outside the unit.
- This is attractive because the stored fuel lasts longer than a charge on a battery.

- It is quicker to refuel a fuel cell than it is to recharge a battery.
- FC produces energy in the form of electricity and heat.
- Fuel cells can be used in applications ranging from portable power at the milli-watt level to megawatt size power plants.

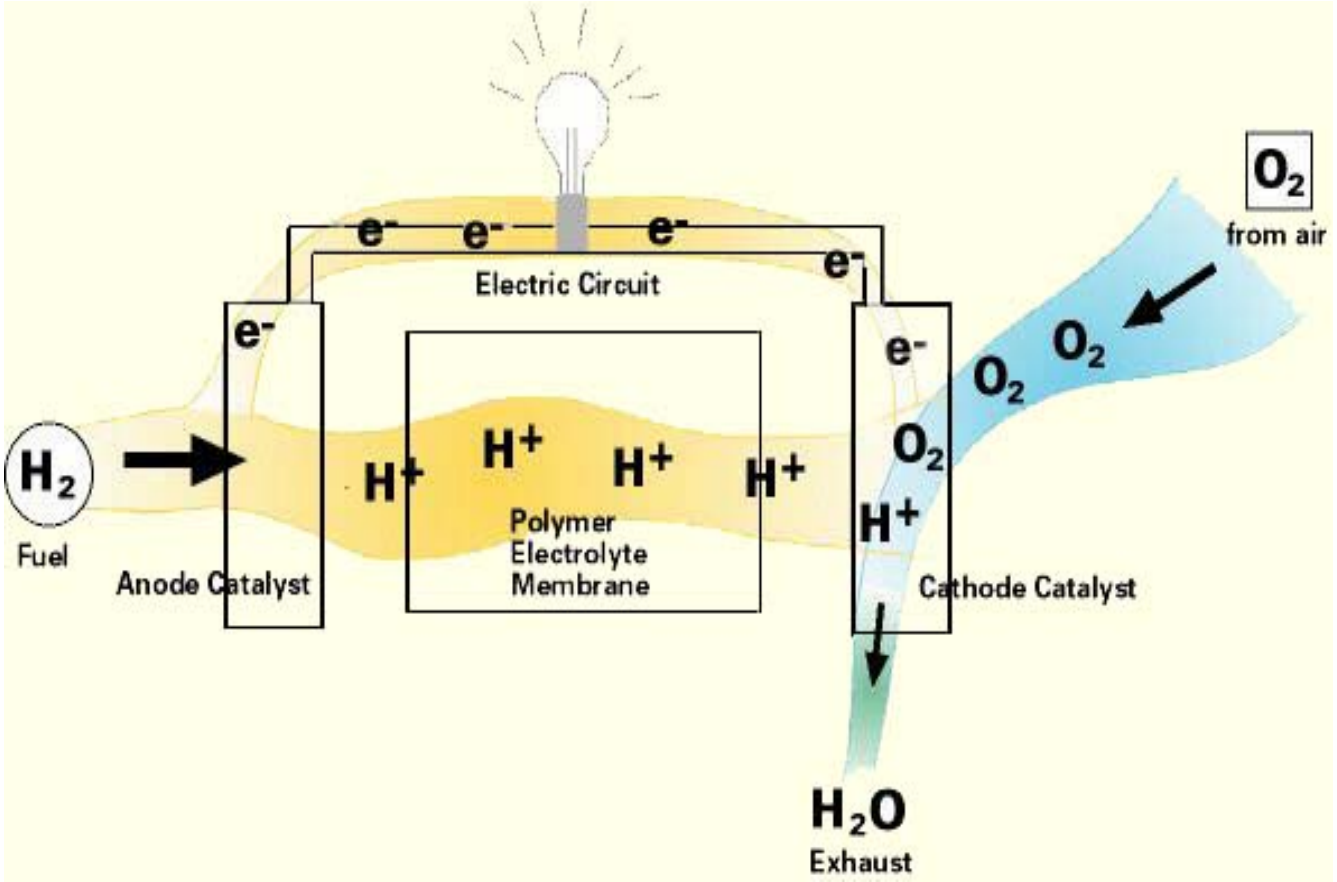
- FC emits carbon dioxide and water as by products without forming NO_x or SO_x gases.

- However two major challenges facing fuel cells:
    1. Cost and
    2. Durability

3. Phosphoric Acid Fuel Cell

- Phosphoric acid fuel cells were the first fuel cells developed as commercial units.
- The PAFC is one of the well known FC with documented performance, and is operated by natural gas.
- Operation temperature: 150 to 200^{o}C.

Phosphoric Acid Fuel Cell Operation
http://www.fuelcells.org



- A fuel cell consists of two electrodes sandwiched around an electrolyte.
- Oxygen passes over one electrode and hydrogen over the other, generating electricity, water and heat.
- Hydrogen fuel is fed into the "anode" of the fuel cell.
- Oxygen (or air) enters the fuel cell through the cathode

- The hydrogen atom splits into a proton and an electron, which take different paths to the cathode.

- The "fuel reformer" utilizes the hydrogen from any hydrocarbon fuel such as natural gas, methanol, and even gasoline.

4. Cell Reactions

- Natural gas, as an example, is used by PAFC to provide the FC with H_2 according to:

$$CH_4+H_2O \rightarrow CO+3H_2.$$

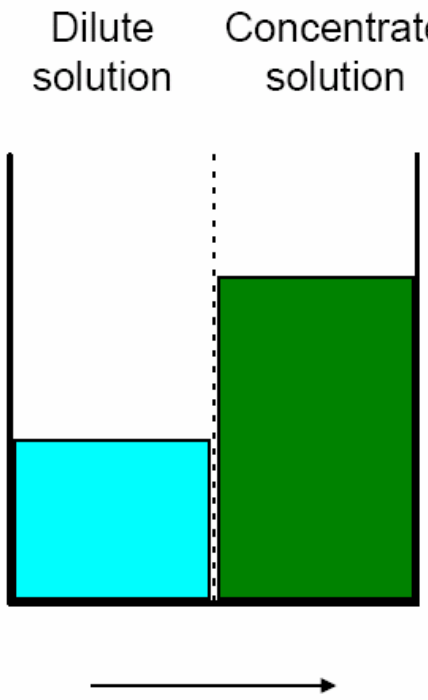
- Excess H_2O is added to reduce CO and to increase H_2 content (water gas shift reaction):

$$CO+H_2O \rightarrow CO_2+H_2$$

- at the anode : $H_2 \rightarrow 2H^{+}+2e^{-}$
- at the cathode : $O_2+2H^{++}+2e^{-} \rightarrow H_2O$
- at the cell : $H_2+O_2+CO_2 \rightarrow H_2O+CO_2$

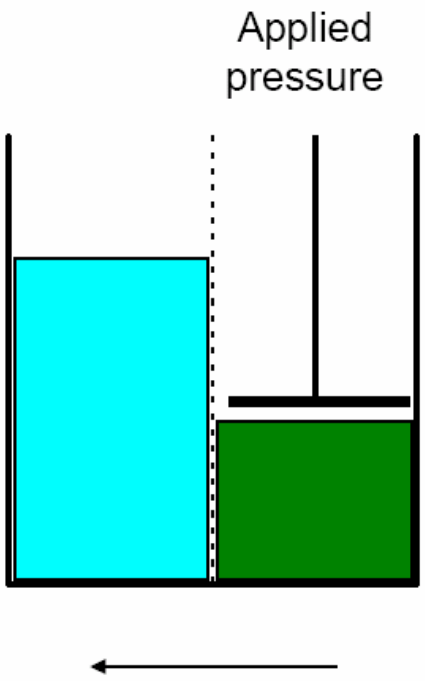
5. Reverse Osmosis (RO) Desalting plant

- When a semi permeable membrane separates fresh water from salty water and both sides have the same pressure P and temperature T.
- Pure water permeates from the fresh waterside to the concentrate side, and this is called osmosis flow.
- When the pressure on the salt waterside is increased the osmotic flow is reversed and water is transferred from the salt waterside to the pure waterside. This is called RO



Osmosis

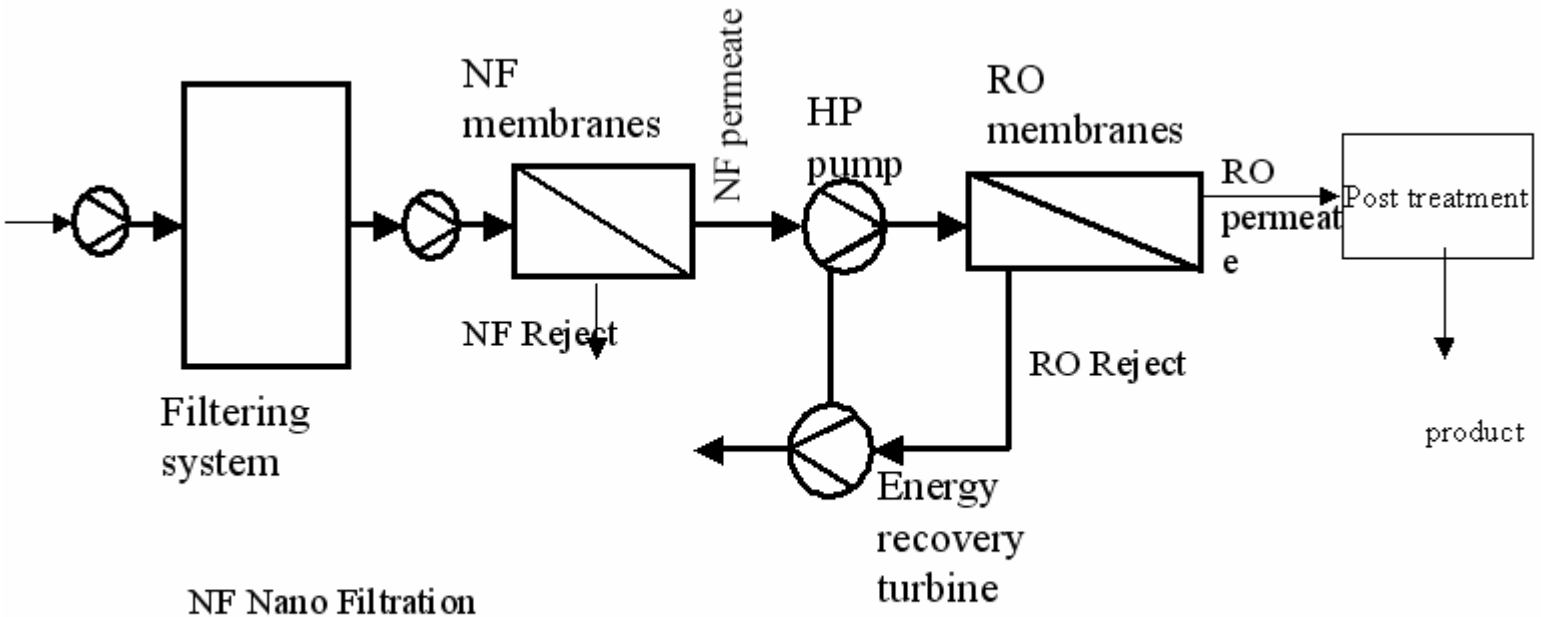
Figure 1a



Reverse Osmosis

Figure 1b

Reverse Osmosis Plant



NF Nano Filtration
RO Reverse
Osmosis

- The phosphoric acid fuel cell PAFC is employed to run the pumps of the RO desalination system.
- This PAFC has 200 kW nominal power capacity.
- The energy consumed by RO plant is 5 kWh/m^3 (18kJ/kg)
- For 18 kJ/kg , the chosen fuel cell of 200 kW can produce about 960 m^3 per day by RO plant.

6. Economy of Owning and Operating FC

1. **PAFC Cost:**
   - **The capital cost : $2020/kW.**
   - **Heat exchanger : $13000.**
   - **Fuel reformer : $15000**
   - **Electrical transformer : $33,000 .**
   - **Fuel cell maintenance : $26,000/yr**

   So, the total cost of the PAFC with auxiliaries in 10 years is $725,000.

2. **Fuel Cost**:

-The FC power production in 10 years is 15,780 MWh, (56,800 GJ).

- The fuel needed in 10 years is 142,000 GJ (40% FC efficiency).

The total fuel cost is $\$7.1 \times 10^5$ based on \$5/GJ of natural gas.

- Then the total cost of PAFC and its fuel, operation and maintenance in 10 years is $1,435,000.

- This makes the cost/kWh is $0.09.

- Therefore, the energy cost to produce one m^3 of desalted water by the RO is $0. 45.

If the cost of the PAFC is decreased to $1000/kW and the cost of fuel is $3/GJ.

Then energy cost per m^3 is reduced to $0.30 ($0.06/kWh)

7. Conclusions

- A study to use 200 kW PAFC to operate RO system is presented.
- The suggested system is able to produce 1204 m^3/d.
- The energy cost produced by the fuel cell is \$0.09/kWh.

- The reduction of the fuel cell cost to $1000/kW will bring the kWh production cost to that of conventional system ($0.06/kWh).
- The environmental benefits of fuel cells should be seriously considered since many of the environmental pollutants associated with combustion-based system do not exist.
- Fuel cell has high efficiency.