Simulation of 3kW Brackish Water Desalination System under Three Design Scenarios

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Abstract: The aim of this study is to simulate three design scenarios of brackish water reverse osmosis (BWRO) desalination system powered by 3kW. The type of membrane used in this study is BW30-4040. Reverse Osmosis System Analysis (ROSA) software is used to determine the performance of membranes, energy requirement for treatment of brackish water (TDS 13,400 mg/L) to provide at least 35 m^3/day of drinking water for 110 households in Mersing, Johor, Malaysia. The simulated configuration designs are single stage with one pressure vessel (scenario I), single stage with two pressure vessels (scenario II) and two stage with one pressure vessel for each stage (scenario III). Scenario II is most accepted compare to scenario I because of its minimum pressure, minimum specific energy and highest permeate flow (45.08m^3/day).

Key-Word: desalination, brackish water, 3kW RO unit, 3 scenarios of design configurations, ROSA software, 3kW RO unit.

1. Introduction

Around 97 % of the water in the world is in the oceans (where, of course, it sustains a wide range of plant and animal life). 25 percent of the world population lives in extremely arid or semi-arid areas, with total lack of good quality fresh water. Moreover, about 1.76 billion people live in areas already facing a high degree of water stress [1]. ‘‘Water stress’’ is at the top of the international agenda of critical problems, at least as firmly as climate change [2]. As a result, the need for desalination is increasing, even in regions where water supply is currently adequate.

The problem is increasing demand for water. The consequential shortage can be tackled in a number of ways including: (1) reducing in leakage and wastage of water during distribution and use; (2) increased recycling of water by both industrial and domestic user; (3) improving the efficiency the water usage. Brackish water has more salinity than fresh water, but not as much as seawater.

Brackish water is also the primary waste product of the salinity gradient power process [3]. According National Research Council (2004), TDS content in brackish water is between 1,000 mg/L to 15.000 mg/L.

One of the most challenging situation of the desalination community is facing today is how to be able to meet the sharply increasing water demand at a cost that can be sustained by the various users. [4] Stated that reduction in cost and the improved economics of desalination plants are essential elements for the development of communities.

[5] Reported that reverse osmosis (RO) technology is ranked among the most appropriate in desalination systems. Reverse osmosis (RO) desalination is a treatment process for production of fresh, low salinity potable water from saline water source (sea or brackish

water) via membrane separation. The mineral/salt content of the water is usually measured by the water quality parameter named total dissolved solids(TDS), concentration of which is expressed in milligrams per liter (mg/L), or parts per thousand (ppt). The World Health Organization (WHO) has established a maximum TDS concentration of 500 mg/L as a potable water standard. This TDS level can be used as a classification limit to define potable (fresh) water [6].

RO systems consist of the following basic components: Feed water supply unit, pretreatment system, high pressure pumping unit, membrane element assembly unit, instrumentation and control system, permeate treatment and storage unit, and cleaning unit. The primary limitations to inland brackish water reverse osmosis (BWRO) desalination are the cost and technical feasibility of concentrate disposal [7-8].

The study evaluated the effect of feed water flow on one stage BWRO system in terms of design, energy consumption, and cost.

2. Material and Method

2.1 Water resource

Water source as sample of brackish water is from Mersing, Johor, Malaysia. Most of residents in Mersing are near about 4-7 km from the sea. The TDS content of water in the area is categorized as brackish water. After tested by conductivity meter, it shows that the TDS content in the water is 13,400 mg/L. The type of membrane that used in this study is BW30-4040.

2.2 ROSA software

The Reverse Osmosis System Analysis (ROSA) software is used to determine the performance of a membrane, energy requirement and desalination cost of fresh water. The ROSA model has been used for designing desalination plants in different parts of the world [9].

The model provides the amount and TDS content of produced water, specific energy and the cost of produced water.

Permeate flow TDS must have acceptable TDS of drinking water without post treatment process (less than 500 mg/L). Energy recovery can also be included in the design. [7] have studied that the energy recovery that can be considered up to 75 % for brackish water.

There are three configuration designs have been studied (scenario I, scenario II and scenario II) to provide 35 m^3/day of drinking water for 110 households in Mersing, Johor, Malaysia. Scenario I is one stage configuration with one pressure vessel with 6-8 membrane elements. Scenario II is one stage configuration with two pressure vessels with 6-8 membrane elements at each pressure vessel. Scenario III is two stage configurations with 1 pressure vessel for each stage with 6-8 membrane elements in each stage.

Figure 1-3 showed the schematic diagrams of 3 kW BWRO for the scenario I, II, ad III respectively using membrane BW30-4040 type. Table 1 shows the numerical values of the necessary input data of desalination cost analysis.

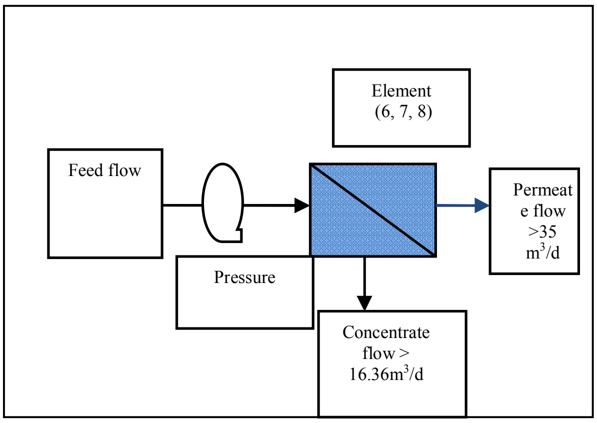

Fig.1 Schematic diagram of one stage/ one pressure vessel of 3 kW BWRO (scenario I)

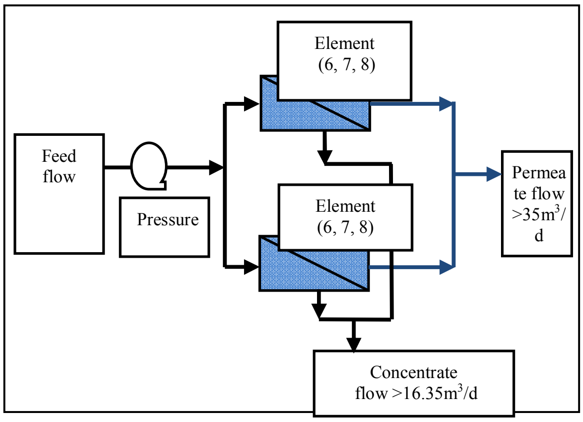

Fig.2 Schematic diagram of one stage/ two pressure vessel of 3 kW BWRO (scenario II)

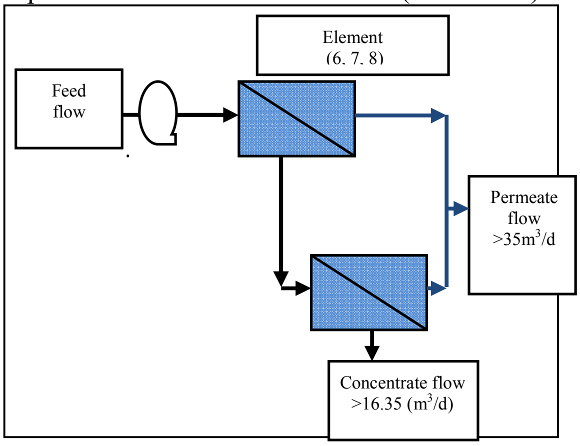

Fig.3 Schematic diagram of 3 kW two stages BWRO (scenario III)

2.3 Design assumptions

1. One stage RO design is
   - With one pressure vessel
   - With two pressure vessels
2. Two stage RO design is with one pressure vessel for each stage.
3. The load of the RO unit is 3kW only.
4. The type of membrane that used in this research is BW30-4040.
5. The permeate TDS is as high as possible but less than 500ppm.

3 Result and discussion

The 3kWRO load shows different working range of feed flow and feed pressure for each scenario, Figures 4-6.

The feed flow and feed pressure range at scenario I, scenario II and scenario III are (50-60m^3/d and 35-39bar), (76-95m^3/d and 22-27bar), and (60-70m^3/d and 30-35bar) respectively.

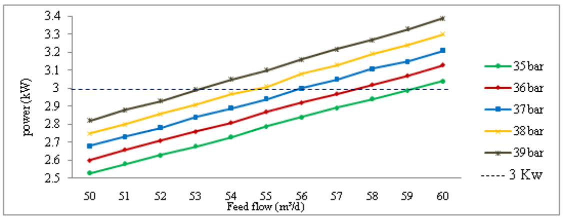

Figure 4 Power versus feed flow at different feed pressure (scenario I)

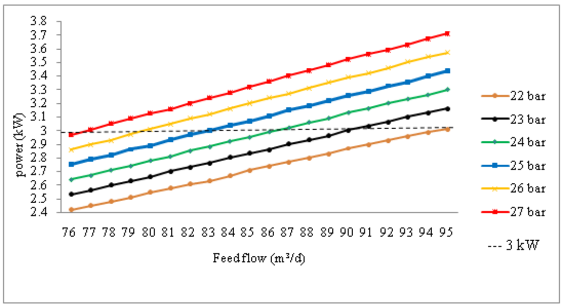

Figure 5 Power versus feed flow at different feed pressure (scenario II)

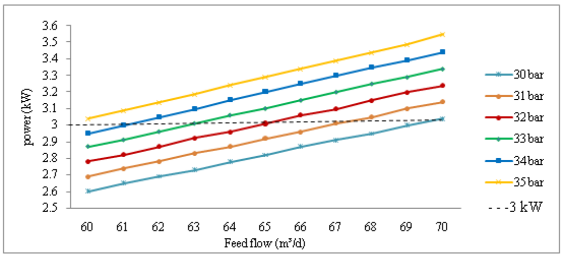

Figure 6 Power versus Feed flow at different feed pressure (scenario III)

Table 2 summarizes the optimum simulation results for all scenarios.

Scenario I shows the minimum feed flow (60m^3/d); the minimum permeate flow (38.25m^3/day), 2nd rank of recovery (63.75%), maximum pressure (35bar) and the maximum specific energy (1.91kWh/m^3) with minimum number of elements (8) and minimum permeate TDS (230mg/L).

Scenario II shows the highest feed flow (77m^3/d); the highest permeate flow

($45.08m^3$/day), minimum recovery (58.55%), minimum pressure (27bar) and minimum specific energy (1.6kWh/m^3) with maximum number of elements (16) and 2nd rank of permeate TDS (346mg/L).

Scenario III shows the 2nd rank of feed flow (67m³/d); the 2nd rank of permeate flow ($43.75m^3$/day), highest recovery (65.3%), 2nd rank of pressure (31bar) and 2nd rank of specific energy of (1.65kWh/m^3) with highest Permeate TDS (404mg/L) and maximum number of elements (16).

Table 2 Simulation results of 3 kW BWRO system

Scenario	Feed flow (m³/d)	Pressure (bar)	Number of element	Permeate flow (m³/d)	Concentrate flow (m³/d)	Perm TDS (mg/L)	Power (kW)	Specific energy (kWh/m^3)	Recovery (%)
I	60	35	8	38.25	21.76	230	3.04	1.91	63.75
II	77	27	16	45.08	31.92	346	3.01	1.6	58.55
III	67	31	16	43.75	23.25	404	3.01	1.65	65.3

3. Conclusion

In this study, three design scenarios are simulated to work under 3kW load of BWRO system to provide 35 m^3/day of drinking water for 110 households in Mersing, Johor, Malaysia. All the scenarios are acceptable for our case study.

1. In terms of simplicity, Scenario I is the most accepted.
2. Scenario II is most accepted compare to scenario I because of its minimum pressure, minimum specific energy and highest permeate flow ($45.08m^3$/day). Using 2 pressure vessels enable the system to produce more clean water with lower feed pressure than one pressure vessel. Feed pressure affect the lifetime of the membrane. Low feed pressure make membrane last longer.
3. Scenario II is most accepted compare to scenario III because of its low pressure, low specific energy and highest permeate flow ($45.08m^3$/day).

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