amount of solids dissolved in the feed stream 18. Thus, it may be necessary to increase the pressure of the brine stream 16 to a higher pressure relative to the pressure of the feed stream 18. A motor-driven, interstage pump (not shown) may be included between the membrane arrays 12, 52 to increase the pressure of the brine stream 16 to this higher pressure. However, since the booster 152 is driven by the hydraulic energy in the brine stream 16, the booster 152 may consume less energy relative to the interstage pump. In addition, using the booster 152 may allow the pressure of the feed stream 18 to be reduced. Thus, the feed pump 20 and the motor 22 may be reduced in size since a reduced amount of pressure is required by them. In addition, the amount of energy consumed by the feed pump 20 and the motor 22 may be reduced.

SUMMARY

[0017] This section provides a general summary of the disclosure, and is not a comprehensive disclosure of its full scope or all of its features.

[0018] A reverse osmosis system according to an aspect of the present invention includes a pump, a first membrane array, a second membrane array, a hydraulic pressure booster, and an electric motor-generator. The pump is operable to pressurize a feed stream. The first membrane array is configured to receive the feed stream and to generate a first permeate stream and a first brine stream from the feed stream. The second membrane array is configured to receive the first brine stream and to generate a second permeate stream and a second brine stream from the first brine stream. The hydraulic pressure booster is configured to receive at least a first portion of the second brine stream and to use energy from the first portion of the second brine stream to increase pressure of at least one of the feed stream and the first brine stream. The electric motor-generator is coupled to the hydraulic pressure booster and is operable to use energy from a power supply to drive the hydraulic pressure booster. The electric motor-generator is also operable to use energy from the second brine stream to provide power to the power supply.

[0019] A reverse osmosis system according to another aspect of the present invention includes a pump, a first membrane array, a second membrane array, a first hydraulic pressure booster, ~~and~~ a second hydraulic pressure

booster and an electric motor-generator. The pump is operable to pressurize a feed stream. The first membrane array is

configured to receive the feed stream and to generate a first permeate stream and a first brine stream from the feed stream. The second membrane array is configured to receive the first brine stream and to generate a second permeate stream and a second brine stream from the first brine stream. The first hydraulic pressure booster is configured to receive a first portion of the second brine stream and to use energy from the second brine stream to increase the pressure of the first brine stream. The second hydraulic pressure booster is configured to receive a second portion of the second brine stream and to use energy from the second brine stream to increase the pressure of the feed stream. The electric motor-generator is coupled to the second hydraulic pressure booster, and is operable to use energy from a power supply to increase the pressure of the first brine stream and to use energy from the second brine stream to provide power to the power supply.

[0020] A method for operating a reverse osmosis system according to another aspect of the present invention includes directing a feed stream to a first membrane array to separate the feed stream into a first permeate stream and a first brine stream, directing the first brine stream to a second membrane array to separate the first brine stream into a second permeate stream and a second brine stream, ~~and~~ controlling a torque output of a motor-generator coupled to a first hydraulic pressure booster to adjust an amount by which the first hydraulic booster increases a pressure of at least one of the feed stream and the first brine stream and controlling the torque output of the electric motor-generator to adjust an amount by which the electric motor-generator provides power to a power supply.

[0021] Further areas of applicability will become apparent from the description provided herein. The description and specific examples in this summary are intended for purposes of illustration only and are not intended to limit the scope of the present disclosure.

DRAWINGS

[0022] The drawings described herein are for illustrative purposes only of selected embodiments and not all possible implementations, and are not intended to limit the scope of the present disclosure.

[0023] FIG. 1 is a schematic view of a first reverse osmosis system according to the prior art;

[0024] FIG. 2 is a schematic view of a second reverse osmosis system according to the prior art;

[0025] FIG. 3 is a schematic view of a third reverse osmosis system according to the prior art;

CLAIMS

What is claimed is:

1. A reverse osmosis system comprising:

a pump operable to pressurize a feed stream;

a first membrane array configured to receive the feed stream and to generate a first permeate stream and a first brine stream from the feed stream;

a second membrane array configured to receive the first brine stream and to generate a second permeate stream and a second brine stream from the first brine stream;

a first hydraulic pressure booster configured to receive at least a first portion of the second brine stream and to use energy from the first portion of the second brine stream to increase a pressure of at least one of the feed stream and the first brine stream; and

~~a~~ an electric motor-generator coupled to the first hydraulic pressure booster, operable to use energy from a power supply to drive the first hydraulic pressure booster, and operable to use energy from the second brine stream to provide power to the power supply.

2. The reverse osmosis system of claim 1 wherein the first membrane array is configured to receive the feed stream directly from the pump.

3. The reverse osmosis system of claim 1 wherein the first hydraulic pressure booster is configured to increase the pressure of the feed stream, and the first membrane array is configured to receive the feed stream after the feed stream flows through the first hydraulic pressure booster.

4. The reverse osmosis system of claim 3 further comprising a variable frequency drive operable to adjust at least one of an amount of power supplied to the electric motor-generator and an amount of load placed on the electric motor-generator to increase the pressure of the feed stream by a desired amount.

5. The reverse osmosis system of claim 4 wherein the first hydraulic pressure booster includes a first variable area nozzle.

6. The reverse osmosis system of claim 5 further comprising a first controller that controls the first variable area nozzle to adjust the flow of the first portion of the second brine stream through the first hydraulic pressure booster and thereby adjust the amount by which the first hydraulic pressure booster increases the pressure of the feed stream.

7. The reverse osmosis system of claim 6 wherein the first controller further controls the variable frequency drive to adjust at least one of the amount of power supplied to the electric motor-generator and the amount of load placed on the electric motor-generator.

8. The reverse osmosis system of claim 6 further comprising a first flow meter that measures the flow of the first permeate stream, wherein the first controller controls the first variable area nozzle based on the flow of the first permeate stream.

9. The reverse osmosis system of claim 8 further comprising a second flow meter that measures the flow of the first portion of the second brine stream, wherein the first controller controls the first variable area nozzle based on the flow of the first portion of the second brine stream.

10. The reverse osmosis system of claim 6 further comprising a second hydraulic pressure booster configured to receive a second portion of the second brine stream and to use energy from the second portion of the second brine stream to increase the pressure of the first brine stream.

11. The reverse osmosis system of claim 10 wherein the second hydraulic pressure booster includes a second variable area nozzle.

12. The reverse osmosis system of claim 11 further comprising a second controller that controls the second variable area nozzle to adjust the flow of the second portion of the second brine stream through the second hydraulic pressure booster and thereby adjust the amount by which the second hydraulic pressure booster increases the pressure of the first brine stream.

13. The reverse osmosis system of claim 12 further comprising a ~~first~~ second flow meter that measures the flow of the second permeate stream, wherein the second controller controls the second variable area nozzle based on the flow of the second permeate stream.

14. The reverse osmosis system of claim ~~13~~ 12 further comprising a second flow meter that measures the flow of the second portion of the second brine stream, wherein the second controller controls the second variable area nozzle based on the flow of the second portion of the second brine stream.

15. The reverse osmosis system of claim 14 wherein the first controller controls the first variable area nozzle based on the flow of the second portion of the second brine stream.

16. A reverse osmosis system comprising:

a pump operable to pressurize a feed stream;

a first membrane array configured to receive the feed stream and to generate a first permeate stream and a first brine stream from the feed stream;

a second membrane array configured to receive the first brine stream and to generate a second permeate stream and a second brine stream from the first brine stream;

a first hydraulic pressure booster configured to receive a first portion of the second brine stream and to use energy from the second brine stream to increase the pressure of the first brine stream; ~~and~~

a second hydraulic pressure booster configured to receive a second portion of the second brine stream and to use energy from the second brine stream to increase the pressure of the feed stream; and

an electric motor-generator coupled to the second hydraulic pressure booster, the electric motor-generator being operable to use energy from a power supply to increase the pressure of the first brine stream and to use energy from the second brine stream to provide power to the power supply.

17. The reverse osmosis system of claim 16 wherein the first hydraulic pressure booster includes a first variable area nozzle.

18. The reverse osmosis system of claim 17 further comprising a first controller that controls the first variable area nozzle to adjust flow of the first portion of the second brine stream through the first hydraulic pressure booster and thereby adjust a first amount by which the first hydraulic pressure booster increases the pressure of the feed stream.

19. The reverse osmosis system of claim 18 wherein the second hydraulic pressure booster includes a second variable area nozzle.

20. The reverse osmosis system of claim 19 further comprising a second controller that controls the second variable area nozzle to adjust flow of the second portion of the second brine stream through the second hydraulic pressure booster and thereby adjust a second amount by which the second hydraulic pressure booster increases the pressure of the first brine stream.

21. The reverse osmosis system of claim 20 wherein the first controller controls the first variable area nozzle based on the flow of the second portion of the second brine stream.

22. The reverse osmosis system of claim 16 further comprising a motor-generator coupled to ~~at least one of~~ the first hydraulic pressure booster ~~and the second hydraulic pressure booster~~.

~~23. The reverse osmosis system of claim 22 wherein the motor-generator is coupled to the second hydraulic pressure booster and is operable to use energy from a power supply to increase the pressure of the first brine stream and to use energy from the second brine stream to provide power to the power supply.~~

~~24~~23. A method for operating a reverse osmosis system, the method comprising:

directing a feed stream to a first membrane array to separate the feed stream into a first permeate stream and a first brine stream;

directing the first brine stream to a second membrane array to separate the first brine stream into a second permeate stream and a second brine stream; and

controlling a torque output of an electric motor-generator coupled to a first hydraulic pressure booster to adjust an amount by which the first hydraulic booster increases a pressure of at least one of the feed stream and the first brine stream; and

controlling the torque output of the electric motor-generator to adjust an amount by which the electric motor-generator provides power to a power supply.

~~25~~24. The method of claim ~~24~~23 further comprising directing at least a first portion of the second brine stream through the first hydraulic pressure booster to increase the pressure of the feed stream by a first desired amount.

2625. The method of claim 25–24 further comprising measuring flow of at least one of the first permeate stream and the first portion of the second brine

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stream and controlling the torque output of the motor-generator based on the flow of the at least one of the first permeate stream and the first portion of the second brine stream.

~~27~~26. The method of claim ~~26~~ 25 further comprising controlling a first variable geometry nozzle of the first hydraulic pressure booster based on the flow of the at least one of the first permeate stream and the first portion of the second brine stream.

~~28~~27. The method of claim ~~27~~ 26 further comprising directing a second portion of the second brine stream though a second hydraulic pressure booster to increase the pressure of the first brine stream by a second desired amount.

~~29~~28. The method of claim ~~28~~ 27 further comprising measuring flow of at least one of the second permeate stream and the second portion of the second brine stream and controlling a second variable geometry nozzle of the second hydraulic pressure booster based on the flow of the at least one of the second permeate stream and the second portion of the second brine stream.

~~30~~29. The method of claim ~~29~~ 28 further comprising controlling the first variable geometry nozzle of the first hydraulic pressure booster based on the flow of the at least one of the second permeate stream and the second portion of the second brine stream.