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 first reverse osmosis system according to the present disclosure includes a pump, a first membrane array, a second membrane array, a hydraulic pressure booster, and a motor-generator. The pump is operable to pressurize a feed stream. The first membrane array is configured to generate a first permeate stream and a first brine stream from a feed stream. The second membrane array is configured to generate a second permeate stream and a second brine stream from the first brine stream. The booster is configured to use energy from the second brine stream to increase pressure of at least one of the feed stream and the first brine stream. The 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 motor-generator is also operable to use energy from the second brine stream to provide power to the power supply.

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

pressure booster, an electric motor-generator and a first controller. 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 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 first hydraulic pressure booster includes a first variable geometry nozzle. 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, (a) is operable to act as a motor to use electric power from a power supply to drive the first hydraulic pressure booster or the second hydraulic pressure booster, and (b) is operable to (i) convert hydraulic energy from the second brine stream into electrical energy and (ii) return the electrical energy to the power supply. The first controller controls the first variable geometry 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 first brine stream. The second hydraulic pressure booster includes a second variable geometry nozzle, characterized in that the motor -generator comprises a torque control.

[0020] A method for operating ~~a~~ the reverse osmosis system according to the first aspect of the present disclosure includes directing a feed stream to ~~a~~ the 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~~ the 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~~ the motor-generator of the second hydraulic pressure booster ~~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.

[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

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 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 first hydraulic pressure booster includes a first variable geometry nozzle; ~~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;

an electric motor-generator coupled to the second hydraulic pressure booster, (a) operable to act as a motor to use electric power from a power supply to drive the first hydraulic pressure booster or the second hydraulic pressure booster, and (b) operable to (i) convert hydraulic energy from the second brine stream into electrical energy and (ii) return the electrical energy to the power supply; and

a first controller that controls the first variable geometry 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 first brine stream;

wherein the second hydraulic pressure booster includes a second variable geometry nozzle, characterized in that the motor -generator comprises a torque control.

~~2. The reverse osmosis system of claim 1 wherein the first hydraulic pressure booster includes a first variable geometry nozzle.~~

~~3. The reverse osmosis system of claim 2 further comprising a first controller that controls the first variable geometry 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 first brine stream.~~

~~4. The reverse osmosis system of claim 3 wherein the second hydraulic pressure booster includes a second variable geometry nozzle.~~

~~5~~2. The reverse osmosis system of claim ~~4~~1 further comprising a second controller that controls the second variable geometry 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 feed stream.

~~6~~3. The reverse osmosis system of claim ~~3~~1 wherein the first controller controls the first variable geometry nozzle based on the flow of the first portion of the second brine stream.

~~7. The reverse osmosis system of any one of claims 1 to 6, further comprising a motor-generator coupled to at least one of the first hydraulic pressure booster and the second hydraulic pressure booster.~~

~~8~~4. The reverse osmosis system of claim ~~7~~1 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.

~~9~~5. A method for operating a reverse osmosis system according to any one of claims 1 to 4, the method comprising:

directing a feed stream to ~~a~~ the 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~~ the 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~~the motor-generator of the second hydraulic pressure booster ~~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.

~~10~~6. The method of claim ~~9~~5 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 first brine stream by a first desired amount.

~~11~~7. The method of claim ~~10~~ 6 further comprising measuring flow of at least one of the first permeate stream and the first portion of the second brine 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.

~~12~~8. The method of claim ~~11~~ 7 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.

~~13~~9. The method of claim ~~12~~ 8 further comprising directing a second portion of the second brine stream though the second hydraulic pressure booster to increase the pressure of the feed stream by a second desired amount.

~~14~~10. The method of claim ~~13~~ 9 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.

~~15~~11. The method of claim ~~14~~ 10 further comprising controlling the 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.