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(Short Paper)

Power Generation of a Large Reverse Electrodialysis (RED) System Based on a Commercial ED stack

Mitsuru HIGA *, Tomoyuki SAKURADA * and Hitoshi TAKEMURA *

Abstract

A large reverse electrodialysis (RED) power generation system based on a commercial electrodialysis stack was built. The system has 200 pairs of cation- and anion-exchange membranes whose effective membrane area was 1000 cm^2. The performance test of the RED system was performed with model seawater (0.5 M NaCl) and model fresh water (various concentrations of NaCl). The power density and gross power output of the system had a maximum value of 0.45 W/m^2 and 17.8 W, respectively, using 0.02 M and 0.5 M NaCl solutions. The calculated pumping energy was 2.76 W; hence, the net power of the system was 15.1 W.

Key Words : Reverse electrodialysis, Power density, Electrodialysis, Salt concentration

1. Introduction

Salinity gradient power (SGP) is a type of renewable energy made possible when two solutions of different salinity mix. The global potential for SGP is calculated to be 2.6 TW when the flow of all the rivers in the world is taken into account[1]. There are two membrane-based technologies that can change SGP into useful electricity: reverse electrodialysis (RED) and pressure retarded osmosis (PRO). In the case of river water with seawater, RED is expected to be a promising technology[2].

There have been many studies on the evaluation of power generation using small RED stacks. However, to the authors' best knowledge, there have been few studies on power generation tests of large RED systems. The aim of this study is to evaluate the power generation properties of a RED system built using a commercial ED stack.

2. Experimental

The RED evaluation system used in this study consisted of an RED stack and a regeneration unit as shown in **Fig. 1**. A commercial ED stack (Acilyzer, AC10-200, Astom Co.) was used as an RED stack. The stack consisted of 200 pairs of power generation units located between cathode and anode compartments. The unit had a cation exchange membrane (CEM), an anion exchange membrane (AEM) and two flow channels of model seawater (SW) and model river water (RW) solutions. The flow channels were made using rubber gaskets (0.6 mm thickness) and plastic nets. The CEM and AEM used in the units were Neosepta AMX

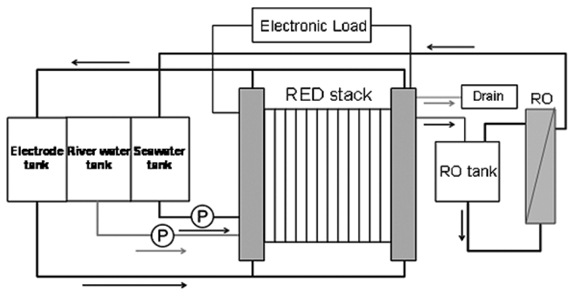

Fig. 1 An evaluation system of an RED stack

and CMX (Astom Co. Japan), respectively. The effective membrane area of each membrane was 1000 cm^2 (20 cm × 50 cm). The cathode and anode were a stainless steel plate and a Pt coated titanium plate, respectively. 5 wt % Na_2SO_4 was used in the electrode solutions. 0.5 M NaCl and NaCl solutions of various concentrations were used as SW and RW, respectively. Each solution was fed into the system by means of liquid feeding pumps. The anode and cathode were connected to an electrochemical measuring device (PLZ 164 W/Kikusui Electronics Co.), which measured the potential difference and impedance through the stack. During an RED performance test, SW was diluted and RW was concentrated by means of ionic transport from the SW side to the RW side. Therefore, the diluted SW and concentrated RW were regenerated to the initial concentration of the SW and RW with the salt regeneration unit performing the test under a steady state condition. The salt regeneration unit consists of a reverse osmosis (RO) membrane module and a high pressure pump.

* Graduate School of Science and Engineering, Yamaguchi University, 2-16-1 Tokiwadai, Ube, Yamaguchi 755-8611, Japan

3. Results and Discussion

Fig. 2 shows an example of the current-voltage curve during the RED test when the concentration ratio of SW to RW, r, = 15. The open circuit voltage of the RED system showed 29.8 V, and decreased as the current increased. When the voltage was zero, the current (short cut current) was 2.97 A. The output power of the RED system had a maximum value of 16.7 W when the load resistance was equal to the inner resistance of the RED system. The I-V curve indicates that the inner resistance of the RED system was 9.8 Ω, which was the sum of the electric resistance of the electrode compartments and 200 pairs of the unit (CEM, AEM, SW and RW channels).

Fig. 3 shows the relationship between the maximum power density (P_{MAX}), and the salt concentration ratio between SW and RW sides (r). The open circuit voltage of the RED system decreased as r decreased because the electromotive force across the membranes decreased as r decreased. The inner-electrical resistance of the RED system decreased as r decreased because the electrical resistance at the RW side of the system decreased as r decreased. Therefore, the P_{MAX} - r curve has a maximum value. Under experimental conditions using 0.02 M and 0. 5 M NaCl solutions (r = 30), P_{MAX} and gross power output had a maximum value of 0.45 W/m^2 and 17.8 W, respectively. The feed pressure of SW and RW were 20.8 kPa and 9.8 kPa, respectively; the feed flow rate of SW and RW were 0.0046 m^3/min and 0.0046 m^3/min, respectively. From these data, the consumption energy of the pumping is calculated as being 2.76 W, assuming the efficiency of the pumping is 85 %. Hence, the net power of the RED system was calculated from the subtraction of the gross power from the consumption energy as 15.1 W. From the results, an RED system will have potential application as an energy converting system from two salinity solutions with different concentrations.

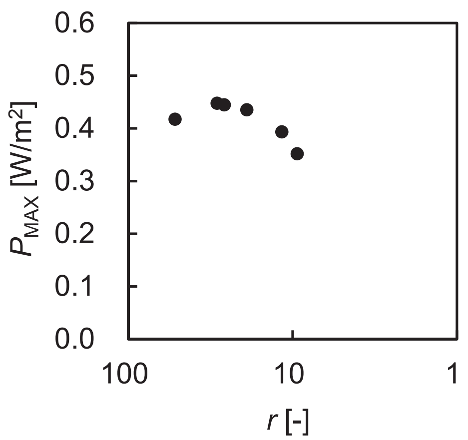

Fig. 3 Maximum power density, P_{MAX}, as a function of the concentration ratio between SW and RW sides, r

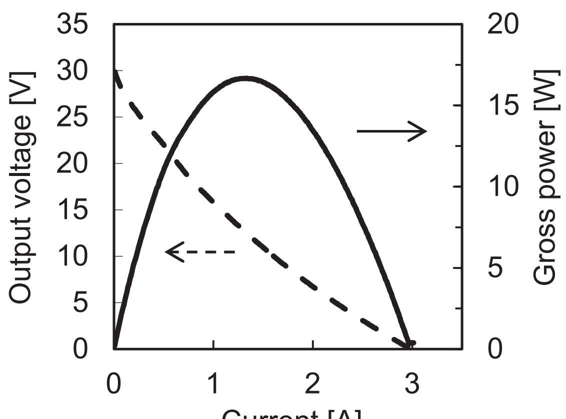

Fig. 2 Output voltage (broken curve), and gross power, (solid curve) as a function of current. The concentration ratio between SW and RW sides, r = 15

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