Reliability evaluation of the performance of reverse electrodialysis

(2 blank lines)
H. Kim[1], J. Y. Nam[1], E. J. Jwa[1], S. C. Yang[1], J. Y. Choi[1] and N. J. Jeong[1*]
(1 blank line)
[1]Jeju Global Research Center, Korea Institute of Energy Research, Jeju, Republic of Korea

(2 blank line)
[*]Corresponding author: njjeong@kier.re.kr

(2 blank lines)

1. Introduction

Salinity gradient energy (SGE) is one of the emerging marine renewable energy source which utilizing mixing enthalpy between different concentrations of feed solutions. Under natural condition, it has about 2.4 TW of global energy potential by mixing seawater and river water [1].

There are several technologies to harvest salinity gradient energy and the reverse electrodialysis (RED) is the most developed electrochemical technology in terms of feasibility. RED consisted of ion-exchange membranes (IEMs) and electrodes. In a RED stack, Ions in a high concentration feed solution are moved to the low concentration feed solution through IEMs. Selective ion transport develops electrochemical membrane potential and it is converted to the electrical potential on the electrodes. Furthermore, on the electrodes, electrical current is generated with proper redox reaction [2].

Analytical methods of the electrochemical performance of RED has been issued because it requires comprehensive understanding about electrochemistry, membrane materials and aquatic chemistry. Measurement of electrical power on the RED stack is dependent to the analytical methods. Not only for RED, but bioelectrochemical system (BES) has similar issue about detecting electrical power under operation condition. It is related with the equilibrium condition of the system and reaction kinetics. However, there was not a proper standard method to compare electrochemical performance of the RED stack [3, 4].

In this study, we compared chronopotentiometry (or chronoamperometry) methods and linear sweep voltammetery method to evaluate reliability of the RED performances.

(1 blank line)

2. Experimental methods

A RED stack consisted of 5 unit cell pairs and a unit cell contained a cation-exchange membrane (CEM), an anion-exchange membrane (AEM) (Fujifilm Type-I, Fujifilm, The Netherland), two spacers and gaskets. As the reference, Fujifilm Type-I membranes were used to secure the properties of membranes and RED performance. Two electrodes were made of Pt/Ti mesh (Wesco electrode, South Korea). Both gaskets and spacers had 0.1 mm of thickness.

Electrochemical performance of RED stack was measured by an programmable direct current (DC) electrical load (Wanayama, Japan) and a potentiostat (ZIVE SP2, Wonatech, South Korea). To measure the highest power on the RED stack by using a DC electrical load, electrical potential was changed in stages. Also, voltage was linearly swept as a 40 mV/s from open circuit voltage to zero by using a potentiostat to measure the highest power density.

(1 blank line)

3. Results and discussions

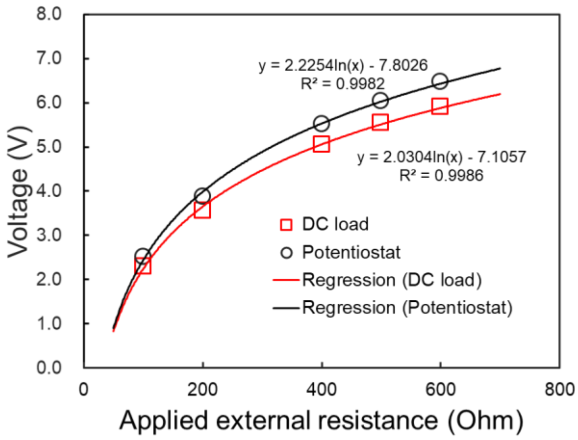

Fig. 1 Voltage (V) – Resistance (R) relation in a single RED stack according to measuring method.

Fig.1 shows the voltage-resistance curves in a single RED stack according to measuring device and method. At a 600 ohm of external resistance, linear sweep method had 9.8% higher voltage than a chronopotentiometric method. It was related with the equilibrium condition of the feed solutions in a RED stack. Voltage on RED was depended on the equilibrium condition between membrane and concentration of feed solution. At a lower electrical resistance condition, ion transport through membrane was fast and the effect of scan rate in linear sweep voltammetry is negligible. However, at a higher external resistance condition, ion transport was not sufficient to make equilibrium condition in a given interval time of chronopotentiometric method.

Fig. 2 shows the current-power density curves in a single RED stack according to measuring methods. The highest power density on a RED stack which measured by potentiostat had 20.6% higher value than a power density measured by DC electrical load. It was induced by promoted kinetics from scan rate of linear sweep voltammetry.

In a practical condition, performance of RED stack would be measured by constant current or constant voltage method. Thus, results from electrical DC load would be more reliable results for understanding performance of the RED stack. However, understanding of internal resistance of RED stack and other kinetics parameter of RED stack could be obtained by using potentiostat. Hence, It would be better to using both measurement methods to obtain reliable results from a RED stack.

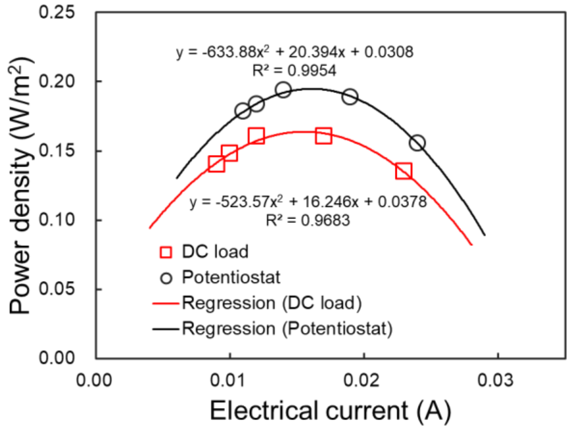

Fig. 2 Current (I) – Power density (P) relation in a single RED stack according to measuring method.

4. Conclusions

In this study, we compared two measurement methods to compare reliability of the performance of RED stack. Both measurement methods are useful to obtain important results of the RED stack. However, to obtain the reliable results of the RED stack, it would be better to understand the meaning of each parameter and figure out optimal measurement condition.

(1 blank line)

Acknowledgment

This research was supported by the Technology Development Program to Solve Climate Changes of the National Research Foundation (NRF) funded by the Ministry of Science and ICT (2017M1A2A2047366).

(1 blank line)

References

[1] Z. Jia, B. Wang, S. Song and Y. Fan. Blue energy: Current technologies for sustainable power generation from salinity gradient, *Renewable and Sustainable Energy Reviews*, 31 (2014) 91-100.

[2] J. Y. Nam, K. S. Hwang, H. C. Kim, H. Jeong, H. Kim, E. Jwa, S. C. Yang, J. Choi, C. S. Kim, J. H. Han and N. Jeong. Assessing the behavior of the feed-water constituents of a pilot-scale 1000-cell-pair reverse electrodialysis with seawater and municipal wastewater effluent, *Water Research*, 148 (2019) 261-271.

[3] H. Kim, M. S. Lee, S. Y. Lee, Y. W. Choi, N. J. Jeong, C. S. Kim. High power density of reverse electrodialysis with pore-filling ion exchange membranes and a high-open-area spacer. *Journal of Material Chemistry A*. 3. (2015) 16302-16306

[4] D. A. Vermaas, M. Saakes, K. Nijmeijer. Doubled power density from salinity gradients at reduced intermembrane distance 45 (2011), 7089-7 095