

Evaluation on a Solar-Driven Membrane Distillator Hybridized with a Photovoltaic Panel (PV/MD)

Kazuo Murase

Department of Applied Chemistry Faculty of Science and Engineering Chuo University

Summary

Renewable and sustainable energies for soft environment are indispensable for sea water technologies, salt and desalination processes, which consume driven energy due to the separation or concentration processes. Solar energy is one of the most practical natural resources by using photovoltaic cells or thermal collectors. However Sea water technologies demand for the mega-scale device due to the low efficiency. A solar-driven membrane distillator hybridized with a photovoltaic panel (PV/MD) simultaneously utilize the photovoltaic and thermal energy of solar energy. The specification contributes to the reduction of a mega-scale device. The heat absorbed by a photovoltaic panel is utilized for membrane distillation directly contacted under the panel, which cools down the panel. The hybridization produces the synergistic effect of photovoltaic (PV) and thermal application. The double glass amorphous-Si PV panel manufactured by Kaneca Co. Ltd. and the polycrystalline-Si panel by Kyocera were respectively selected for water resistance and high conversion efficiency, which depends on cell temperature. A flat type of air gap membrane distillation (AGMD) using PTFE membrane by Nitto denko Co. Ltd. produces distilled water driven by solar thermal energy. The energy saving efficiency was experimentally and numerically evaluated for validity of a hybrid PV/MD due to the various energy grades. The optimal operational and design parameters depend on application for desalination or salt concentration. A double effect membrane distillator with a photovoltaic panel (PV/MEMD) was investigated in the laboratory test using a solar simulator in order to improve the distillate productivity. The improvement of MD was a negative factor for electric conversion efficiency due to the reduced cooling effect of cell temperature by MD. The electrical conversion efficiency primarily contributes to advance energy saving efficiency due to the electric power generation efficiency for a conventional power plant. Case studies of a single PV, PV/MD without flow rate, PV/MD without a phase change, PV/MD and PV/MEMD with parallel or counter flow were experimentally and numerically facilitated for the validity of hybridization of PV with MD. The optimal condition of PV/MD depends on salinity and the flow rate of sea water. PV/MD is classified into desalination device but functions as a salt concentrator at the low concentrate ratio for the emphasized electric generation. The integrated processes of PV/MD with sea water technologies driven by electric power, ED or RO were estimated for the total utilization of sea water technologies

The Development of a Reverse Electrodialysis (RED) System and Evaluation of the Feasibility

Mitsuru Higa

Applied Fine Chemistry, Graduate School of Science and Engineering, Yamaguchi University

Summary

Salinity gradient power (SGP) is a renewable energy that is available when two solutions of different salinity mix. The global potential for SGP is calculated to be 980GW when the flow of all rivers in the world is taken into account. There are two membrane-based technologies that can change SGP into useful electricity: reverse electrodialysis (RED) and pressure retarded osmosis (PRO). The key components in a RED system are ion-exchange membranes (IEMs). This study evaluates the potential of commercial IEMs and poly (vinyl alcohol) (PVA)-based IEMs for application in RED. We have prepared PVA-based IEMs from PVA and polyelectrolytes. The basic transport properties for RED operation: the membrane resistance and ionic selectivity of the IEMs were measured by using conventional methods. We have built a simulation method for theoretical power density of RED by substituting the values of the transport properties into the equations of the simulation. The obtained theoretical power density of a RED cell with PVA-based IEMs was compared with that with commercially-available IEMs (Neosepta CMX and AMX).

The RED stacks used in this study consist cation exchange membranes (CEMs) and anion exchange membranes (AEMs) that are piled in an alternating pattern between a cathode and anode. The cathode and the anode were AgCl and Ag plates, respectively. Electrode solutions (3M NaCl), the concentrated salt solution (0.5 M NaCl, “seawater side”), and the diluted salt solution (various concentrations of NaCl, “river water side”) were fed to the stack. The two types of spacer: 1.0 mm and 0.5 mm were used in the RED tests to control the inter-membrane distance.

The open circuit voltage of the RED system decreases with decreasing the concentration ratio between the sea water and the river water side solutions (r) because the electromotive force across the CEMs and AEMs decreases with decreasing r . The inner-electrical resistance of the system increases with increasing r because the electrical resistance at the river water side of the system increases with r . Therefore, the maximum power density, P_{MAX} of the commercial IEMs was 0.58 W/m² when r was about 20. P_{MAX} of the PVA-based IEMs was lower than that of the commercial IEMs because of the effect of the internal concentration polarization of the support layer of the PVA-based IEMs on the decrease in the effective concentration ratio between the seawater and river water sides.

The development of a RED stack with high power density and high anti-fouling properties, and a pretreatment system with low energy consumption will be essential.

Integrated Sea Water Technologies with a Solar-Driven Membrane Distillator Hybridized with a Photovoltaic Panel (PV/MD) and Reverse Electrodialysis (RED)

Kazuo Murase¹, Mitsuru Higa²

¹Department of Applied Chemistry, Faculty of Science and Engineering, Chuo University

²Applied Fine Chemistry, Graduate School of Science and Engineering, Yamaguchi University

Summary

Renewable and sustainable energies for soft environment are indispensable for sea water technologies, salt and desalination processes, which consume driven energy due to separation or concentration processes. The energy saving and the treatment of discharged concentrated salinity from the primary desalination process such as RO should be mainly resolved in sea water technologies. The developments of a solar-driven membrane distillator hybridized with a photovoltaic panel (PV/MD) and reverse electrodialysis (RED) are promising technologies as electric power generations using alternative energy resources.

PV/MD directly composes of a photovoltaic panel (PV) for electric power generation by solar photovoltaic energy and a membrane distillator for desalination by solar thermal energy. Direct hybridization reduces the mega-scale installation area and advances the double energy saving efficiency of electric conversion and thermal efficiencies. The dependence of a cell temperature on electric conversion demands for cooling effect of a PV panel by MD and absorbed thermal energy in PV panel is recovered into distillation.

On the other hand salinity gradient power technologies such as RED and pressure retarded osmosis (PRO) are largely respected for osmotic energy recovery (OER) and reduction of waste seawater effluent from desalination process. RED has several advantages of equivalent ED technology and no additional device of hydraulic generation compared with PRO. Moreover a new type of ion exchange membrane optimal for RED and an alternative simulation method for theoretical power density have been developed.

The integrated sea water processes of the primary technologies such as RO, ED or combined ED-RO with a PV/MD and a RED stack will be respected for the low consumption of specific energy and sea water resources.