Closed circuit PRO series no 3: status and prospects for PRO hydroelectric power generation from sea–river water like salinity gradients

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ABSTRACT

The present status and future prospects of pressure related osmosis (PRO) for hydroelectric power generation from the most widespread salinity gradients of seawater and river water systems (SW–RW) are analyzed by a theoretical model in terms of the membrane, module, and method. The selected membrane in the model analysis comprises MP # 1 of the highest presently known permeability coefficient (5.81 Lmh/bar) with a projected peak power density of 10 W/m² at 13 bar. The performance of the referred MP # 1 membrane was ascertained in the context of the closed circuit PRO (CC-PRO) and conventional PRO methods at different HSF (high salinity feed or “draw” solution) to permeate flow ratio (δ), and percent permeate (α) in HSDF (high salinity diluted feed or diluted “draw” solution) with emphasis on the membrane power density (PD) and the net electric power density (NEPD) which takes into account the fraction of power consumed by the auxiliary pumps. The theoretical CC-PRO simulation of a typical SW–RW salinity gradient using MP # 1 with actual/ideal flux ratio (β) of 0.374 shows maximum membrane PD as function of flow ratio (δ) and hydraulic pressure difference in the declined order of 10.00 W/m² at 13 bar (δ > 40); 8.52 W/m² at 12 bar (δ = 5.0); 7.45 W/m² at 11 bar (δ = 2.5); 6.13 W/m² at 10 bar (δ = 1.25); 5.69 W/m² at 10 bar (δ = 1.00); and 5.16 W/m² at 9 bar (δ = 0.75). The simulated NEPD availability of this system reveals the declined order of 4.2 W/m² at 13 bar (δ = 2.5); 4.1 W/m² at 12 bar (δ = 1.25); 3.9 W/m² at 11 bar (δ = 1.00); and 3.6 W/m² at 10 bar (δ = 0.75). Compared with the CC-PRO technology of near absolute energy conversion efficiency, the PD and NEPD of the conventional PRO technique with MP # 1 show lower values since they depend on the efficiency of the energy recovery device. A further decline of PD and NEPD availability also takes place for membrane having A < 5.81 Lmh/bar and/or β < 0.374, suggesting the low feasibility of the SW–RW gradient systems for economic PRO hydroelectric power generation in the near future.

Keywords: Forward osmosis; Osmotic power; Salinity gradient power; Osmotic power generation; Pressure retarded osmosis (PRO); Closed circuit PRO; Osmotic gradient driven processes; Clean energy sources