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STRAY CURRENTS AND ENERGY EFFICIENCY OF ATMOSPHERIC AND PRESSURIZED ALKALINE WATER ELECTROLYZERS

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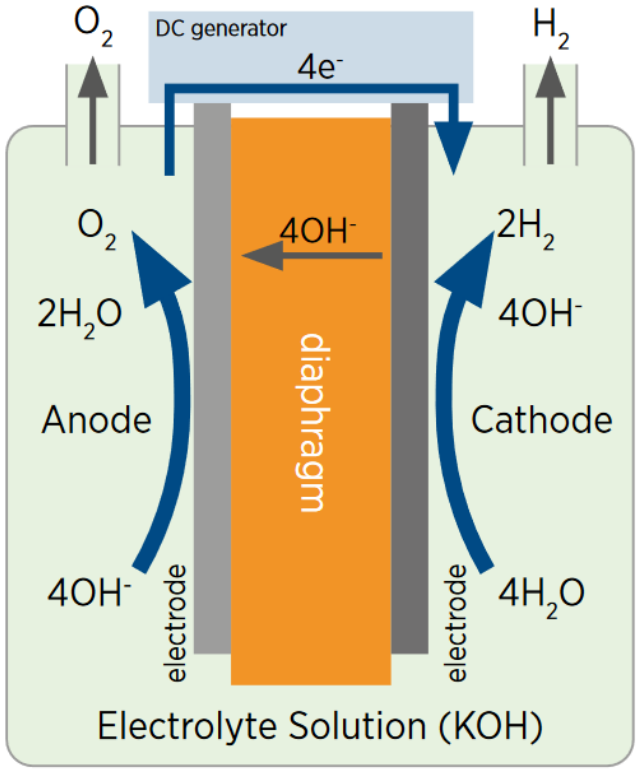
Funding and projects:

THE ALKALINE WATER ELECTROLYZER

Cell level



Anode: $4OH^- \leftrightarrow 2H_2O + O_2 + 4e^-$

Cathode: $4H_2O + 4e^- \leftrightarrow 2H_2 + 4OH^-$

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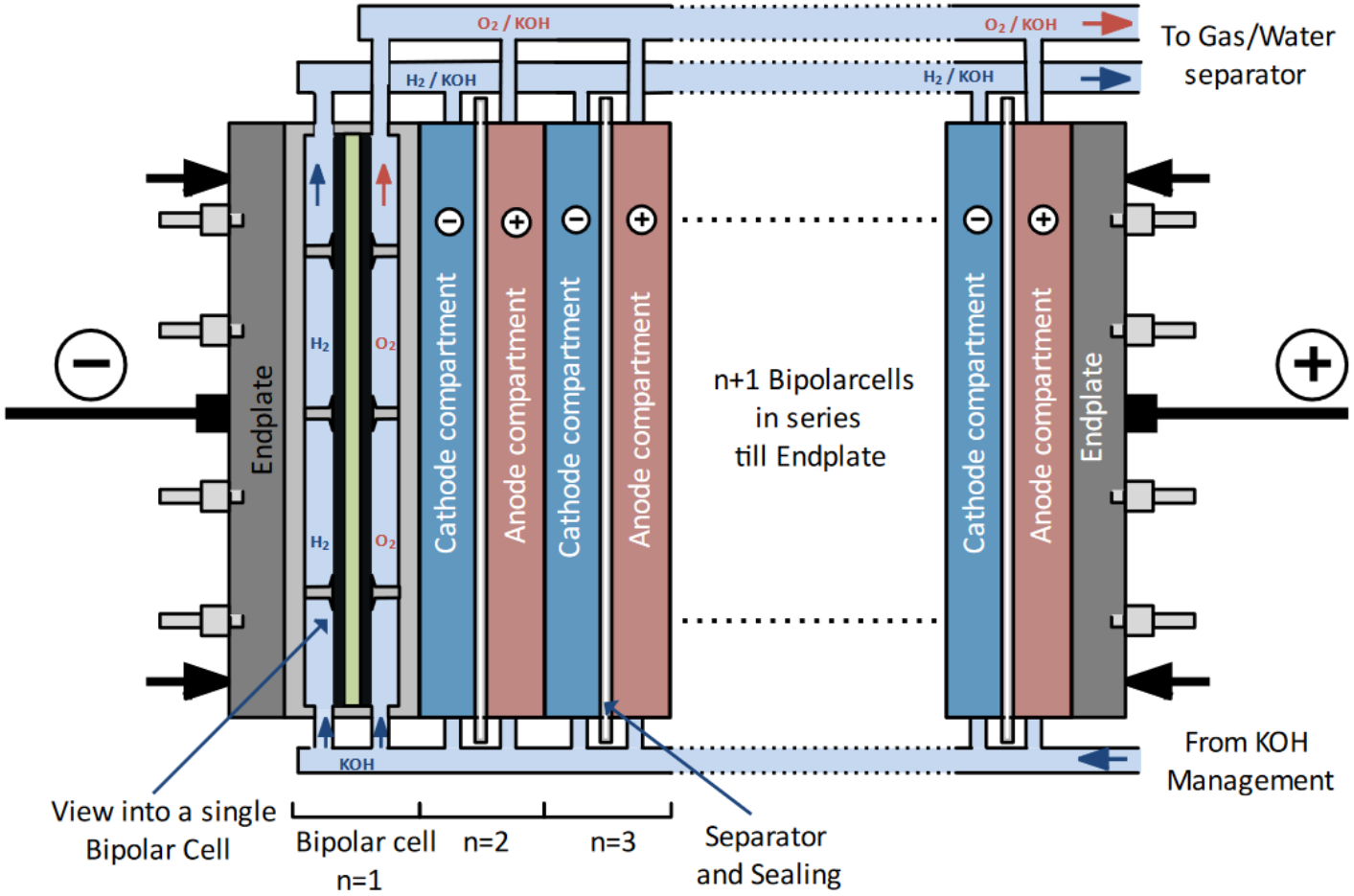
Stack level



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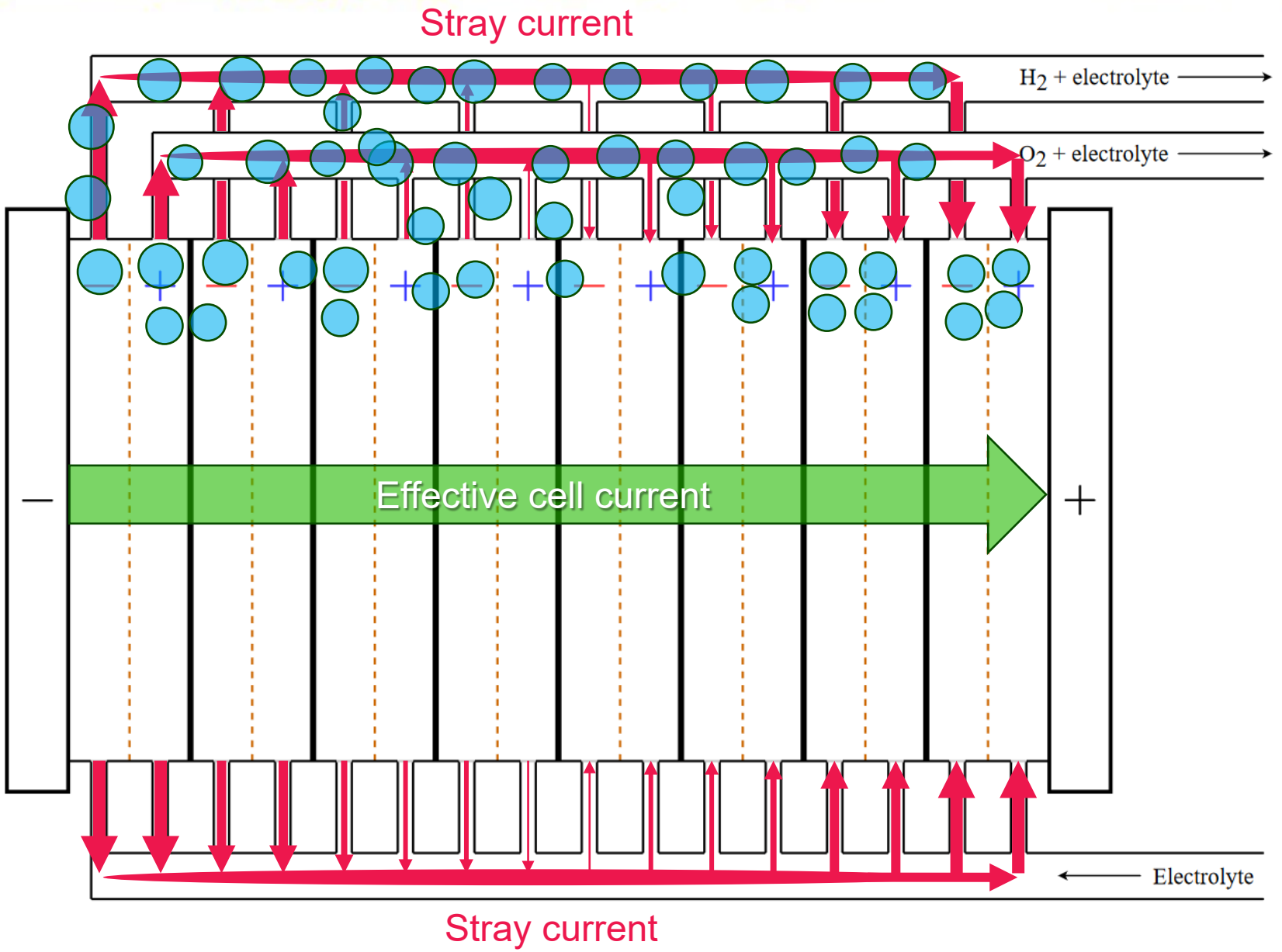
THE CAUSE OF STRAY CURRENTS

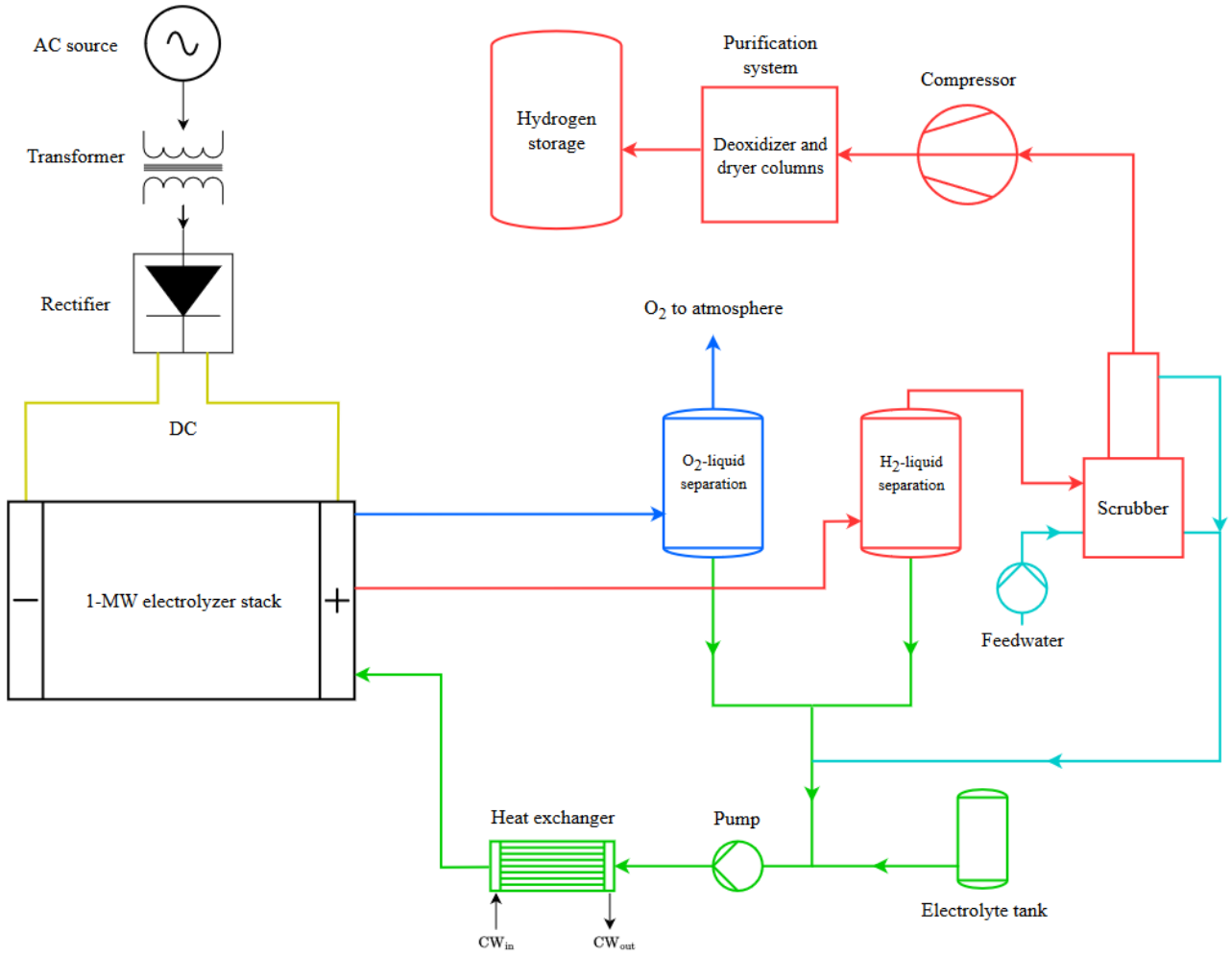
- Fluid channels present a parallel path for current, bypassing the electrochemical reaction
  - Total supplied current = effective cell current + stray current
- Magnitude of stray currents is determined by:
  - Stack design
    - Port and manifold dimensions, number of cells
  - Electrolyte conductivity
    - Temperature, KOH concentration
  - Stack outlet manifold gas volume fraction



STRAY CURRENTS IN PRACTICE

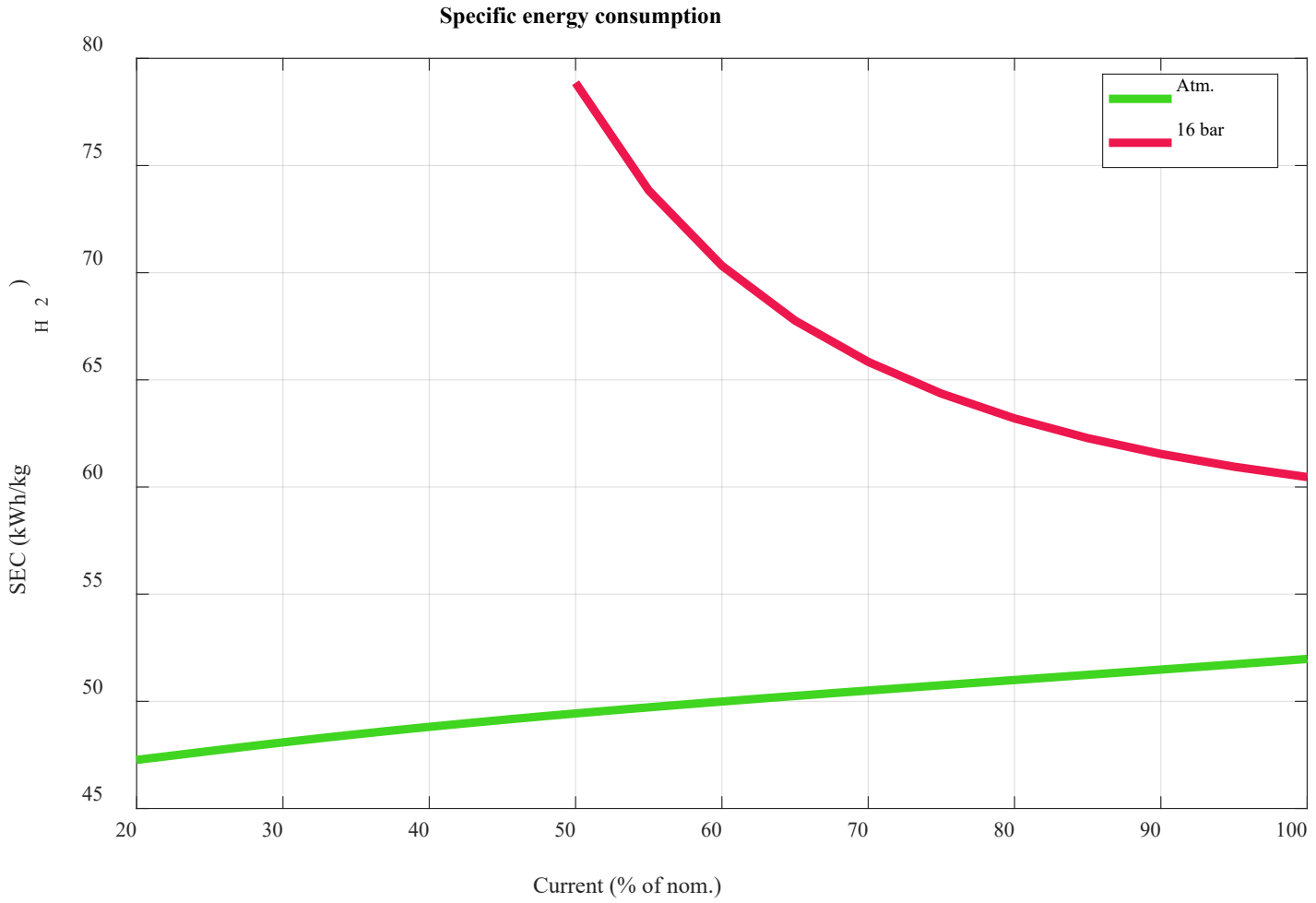
Results from two industrial case studies and our research

- LUT alkaline plant model
  - Simulink/MATLAB
  - Dynamic mass and energy balance of each plant unit operation
  - Parameters fitted to measurement data from real industrial systems:
    - 3 MW, 16 bar
    - 1 MW, atmospheric
  - Goal:
    - Determine proportions of energy losses as a function of load, stack temperature, electrolyte flow rate, system pressure



STRAY CURRENTS IN PRACTICE

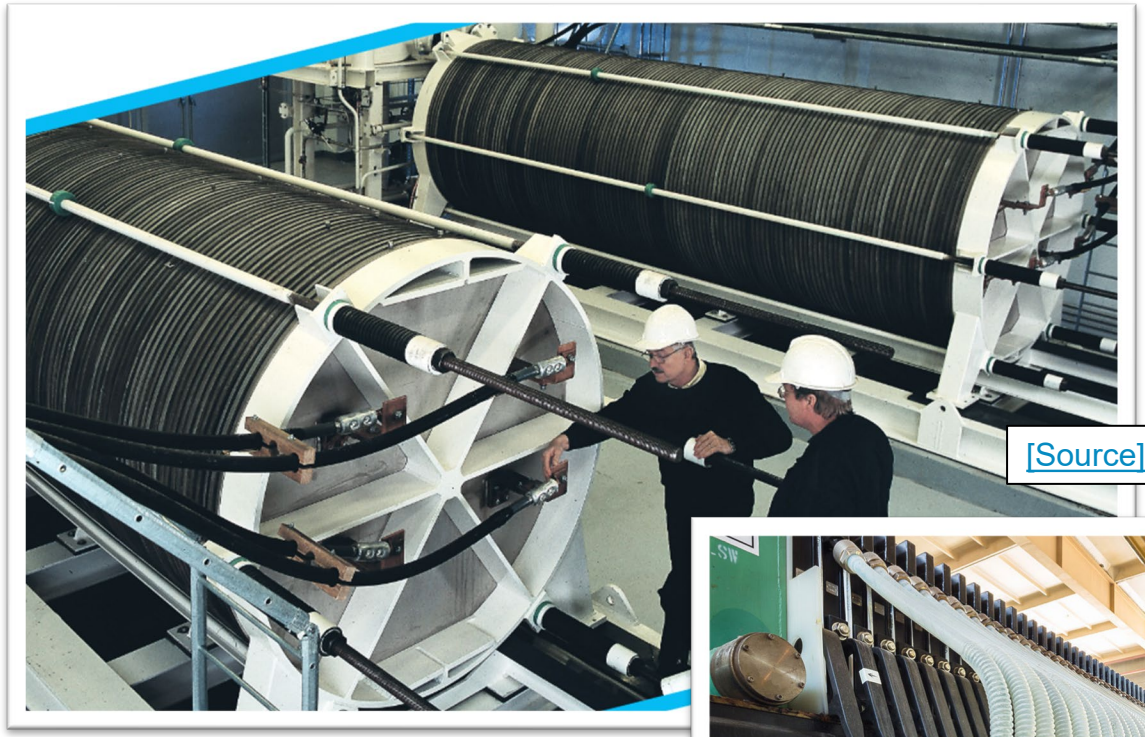
Results from two industrial case studies



- Current efficiency at nominal load
  - 99% in the atmospheric system
  - 83% in the pressurized system, with notable drop towards smaller loads
- Stray currents increase SEC of pressurized stack at partial loads
- Differences between studied systems
  - Stack length
  - Gas volume fraction
  - Electrolyte port and manifold design

REDUCING STRAY CURRENTS

- Maintain high gas volume fraction to block outlet-manifold stray currents
  - Easier to achieve in an atmospheric system, where higher rate of water vaporization provides extra stack cooling and allows lower electrolyte flow rates while keeping temperature difference through stack in check
- Limiting stack length
  - Lower voltage driving the stray currents
  - Higher resistance stray current path
  - CAPEX vs OPEX; optimal stack length?
- Manifold and port dimensioning
  - Compromise between manufacturability and energy efficient design



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CONCLUSION

Stray currents

- inherent feature of the alkaline bipolar cell stack
- result of bipolar stack design, not a consequence of electrochemical properties
- more of a challenge in pressurized systems
- can waste dozens of percent of the power supplied to the stack
  - affects especially partial-load operation (important to renewables-based H_2 !)
- can be limited with good design

Sakas et al., Sensitivity analysis of the process conditions affecting the shunt currents and the SEC in an industrial-scale alkaline water electrolyzer plant, https://doi.org/10.1016/j.apenergy.2024.122732

Sakas et al., Influence of shunt currents in industrial-scale alkaline water electrolyzer plants, https://doi.org/10.1016/j.renene.2024.120266


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THANK YOU!
QUESTIONS, COMMENTS?