Grid Integration and Operation of Large-Scale Hydrogen Electrolyzers

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Background and Research Motivation

Global Approach of Large-scale Hydrogen Electrolysis Plants

AGA seals deal with Plug Power for 3 GW electrolyser system

Allied Green Ammonia has signed and sealed a purchase agreement with Plug Power to supply 3 GW of electrolyser capacity for its large-scale green hydrogen production project being developed in the Northern Territory.

JANUARY 20, 2025 DAVID CARROLL

New 6 GW plant in Western Australia to spearhead hydrogen exports

The wind-solar plant is set to export ammonia to Japan and Korea in early 2030s.

16 May 2025

A new 6 GW green hydrogen plant looks set for construction on the coast of Western Australia, starting in 2027. The Murchison Green Hydrogen Project (Murchison) will be among the first wave of export-level hydrogen plants in Australia.

Siemens Energy wins contract for large-scale hydrogen project from German utility EWE

Press release July 25, 2024 Berlin

Siemens Energy has been awarded a contract to supply a 280-megawatt electrolysis system by German utility EWE. The plant in the German city of Emden is expected to go into operation in 2027 and will provide up to 26,000 tons of green hydrogen annually for various industrial applications in the region. If this green hydrogen replaces fossil fuels, around 800,000 tons of CO_2 per year could be avoided in the steel industry, for example.

Press information

July 2, 2025
Tokyo
Siemens Energy's El
Decarbonize Semicc

235 kgs Targeting an initial production of 235 kilograms (kgs) per day of hydrogen

1,000 kgs Potential to scale up to approximately 1,000 kgs per day of hydrogen

2.6 MW The facility will have a 2.6 megawatt electrolyser

2026 First hydrogen production targeted for first half of 2026

Background and Research Motivation

Electrolyzers are inverter-based loads. Can they provide more than hydrogen??

Figure 13: AWE modular design

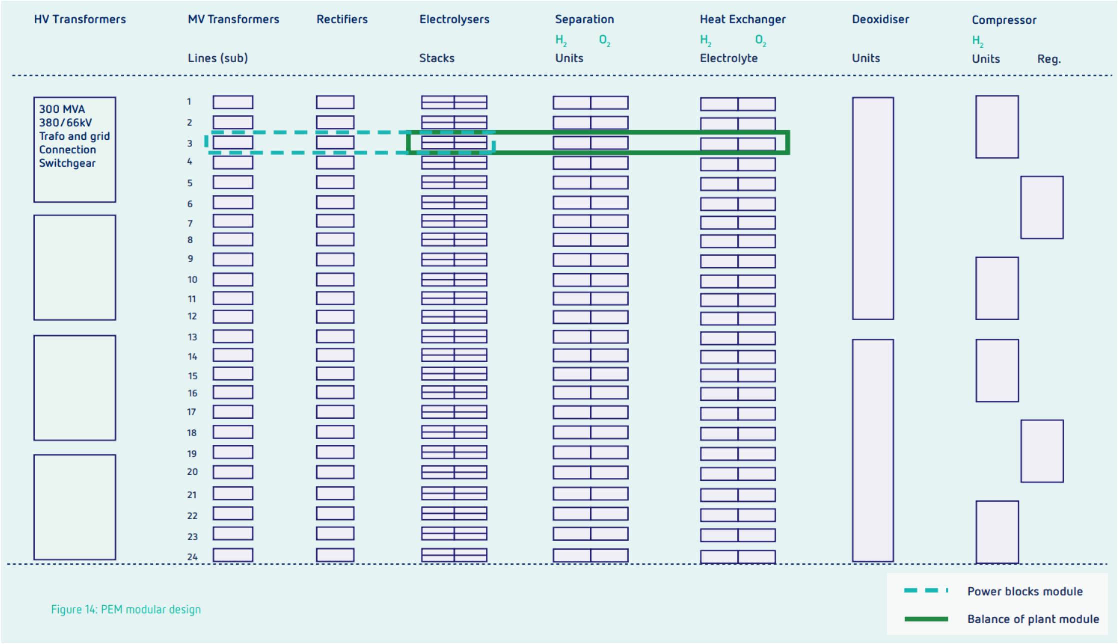


Figure 14: PEM modular design

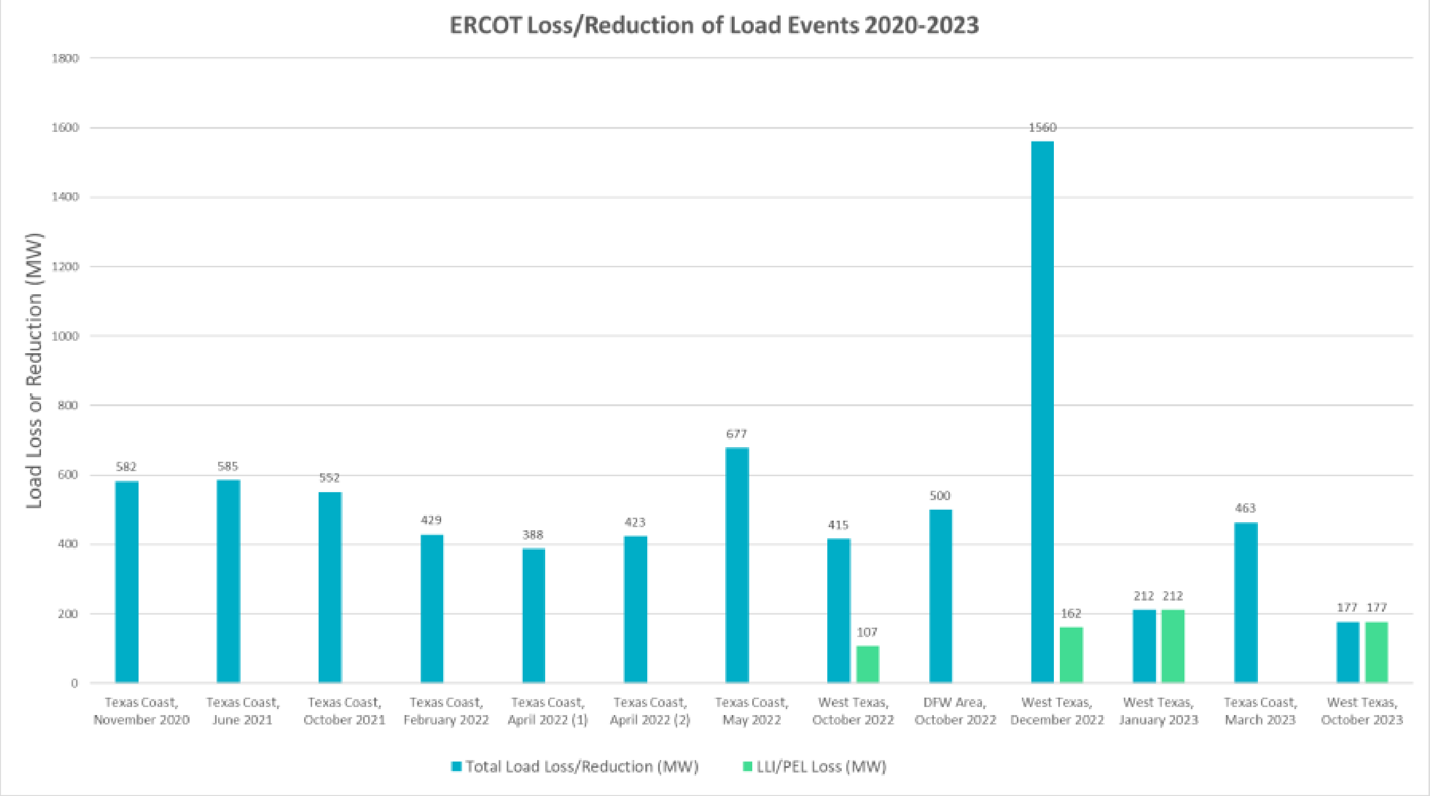
Does the scale-up strategy matter in the provision of system services??

Does it impact the footroom and headroom available for the service provision, and the speed of the response??

Source -"A one-gigawattgreen-hydrogen plant: Advanced design and total installed-capitalcosts," Institute for Sustainable Process Technology (ISPT),Amersfoort, The Netherlands, Tech. Rep. Hydrohub GigaWatt-ScaleElectrolyser project report, 2022

Background and Research Motivation

Unexpected tripping of large loads



1. **Why do large electrolysis plants trip?**
2. **Do we have the necessary grid-code requirements for scaled-up electrolysis plants?**
3. **How to define those grid codes?**
4. **How to mitigate those unexpected tripping?**

Source: https://www.ercot.com/files/docs/2024/11/18/ERCOT%20Large%20Load%20Events_PDCWG_19Nov2024.pdf

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Research Gaps

G1

Dynamic Modelling & Control of Scaled-up Hydrogen Electrolysis (HE) Plants
Existing studies largely rely on single-stack or simplified models to represent scaled-up, multi-stack electrolysis plants.

G2

Power Dispatch and Coordination
Limited understanding of how power dispatch strategies and coordination among multiple stacks impact the provision of system services.

G3

Fault Ride-Through (FRT) Capability
The FRT capability of scaled-up, multi-stack HE plants remains underexplored, particularly under grid-code conditions.

G4

Techno-Economic Consideration
Techno-economic implications of scaling up hydrogen electrolysis are rarely addressed.

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Research Questions

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G1 **Dynamic Modelling & Control of Scaled-up Hydrogen Electrolysis (HE) Plants**

G2 **Power Dispatch and Coordination**

G3 **Fault Ride-Through (FRT) Capability**

G4 **Techno-Economic Consideration**

RQ1 Why is a **single-stack representation insufficient** to capture the dynamic behaviour of scaled-up HE plants, and what **really matters** when scaling up hydrogen electrolysis?

RQ2 What are the **different power dispatch strategies** that can be employed for power sharing among stacks, and how do they impact the **provision of system services** and **HE efficiency**?

RQ3 **To what extent** can scaled-up HE plants **tolerate grid faults** without **disconnection**, and what are the **possible ways** of **improving** FRT capability?

RQ4 How do we perform a techno-economic assessment of different **electrolyser technologies**, **power dispatch strategies**, and **power electronics requirements** in multi-stack, scaled-up HE plants?

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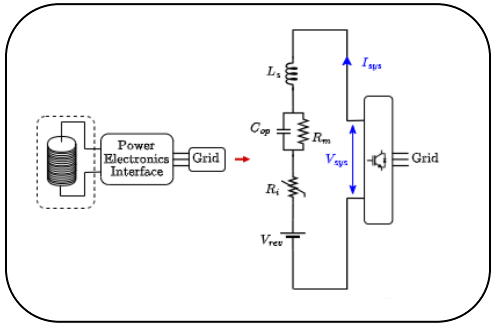
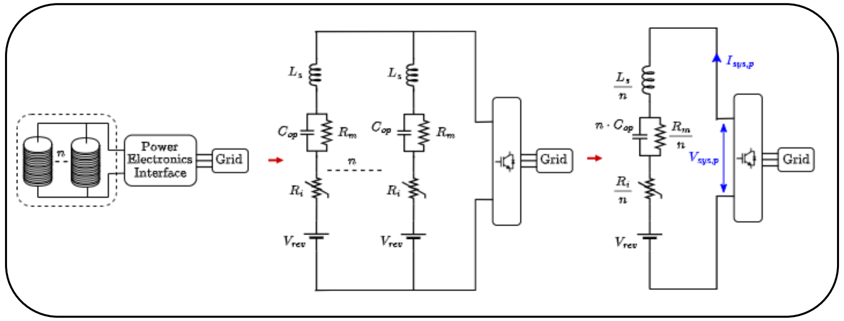
Impact of the modeling of multi-stack electrolysis plants and the impact on the polarization curve

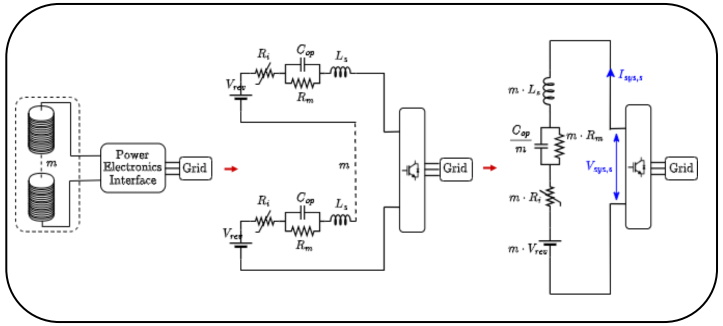
Single-stack model



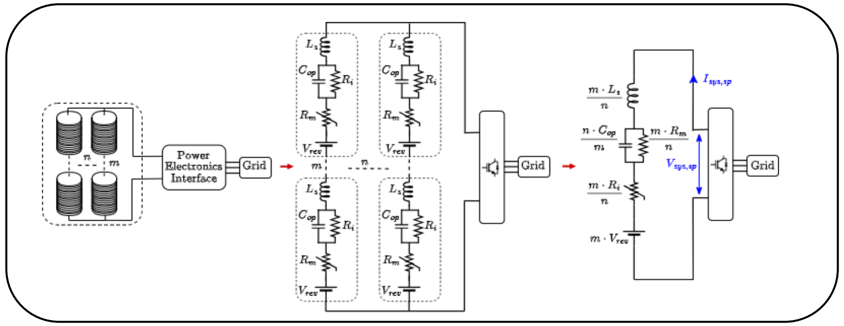
Parallel connection

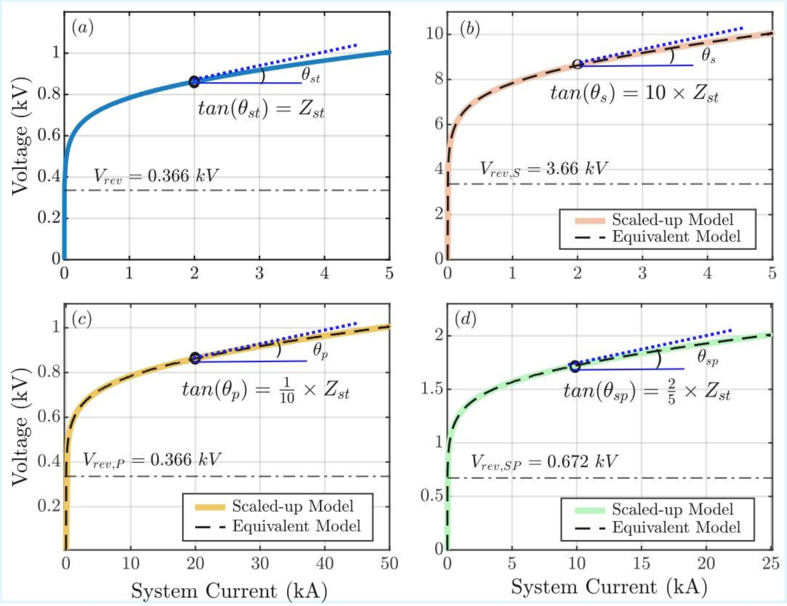


Series connection



Series- parallel connection



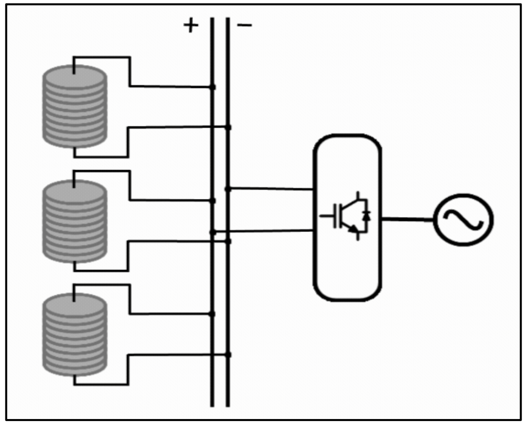


HE polarisation curves: (a) single-stack, (b) series connection, (c) parallel connection. (d) series-parallel connection

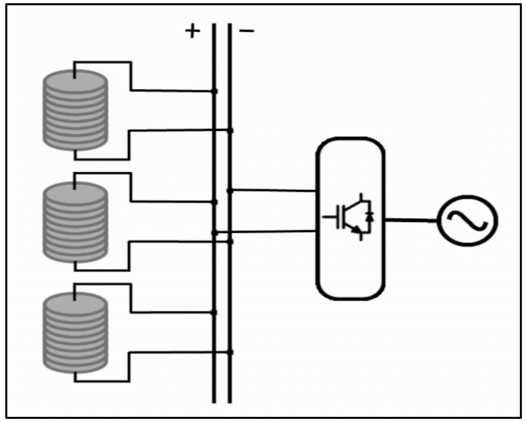
Current Progress and Results

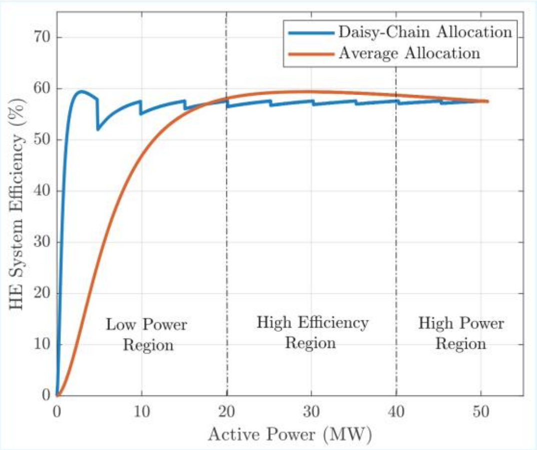
Dispatch strategies in scaled-up plants impact on the system service provision and HE efficiency

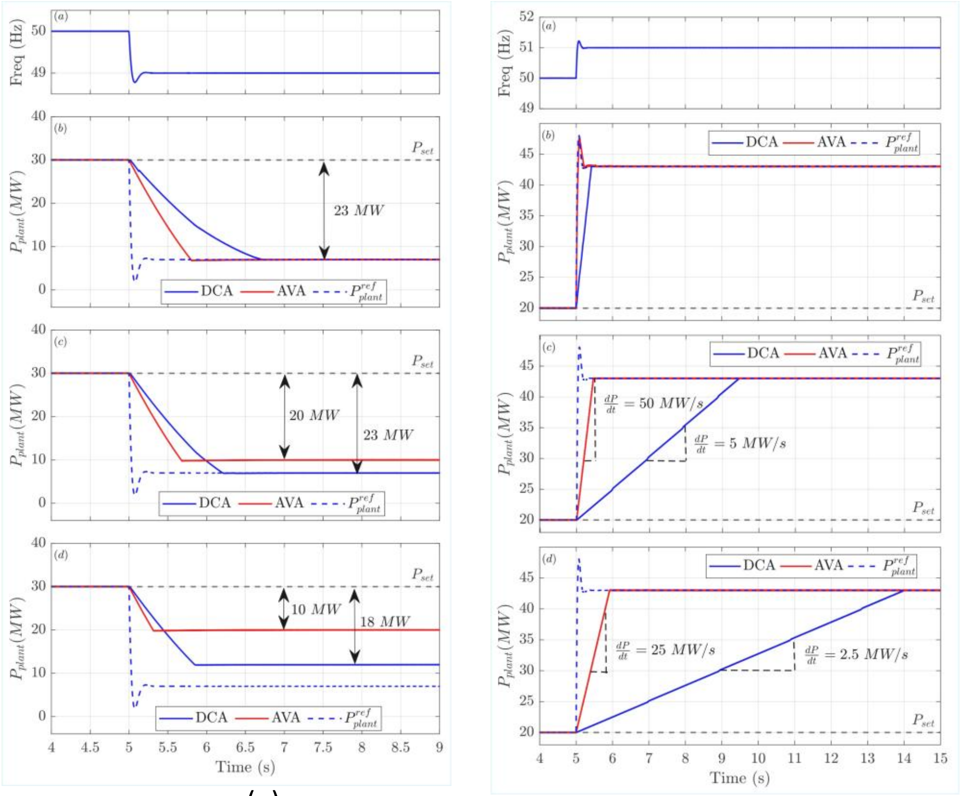
Average Allocation Strategy



Daisy-chain Allocation Strategy







(a)

(b)

Power dispatch strategy impacts on, (a) HE frequency response volume and the whole-plant partial load limit,(b) HE frequency response speed and the whole-plant ramp rate limit.

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1. Optimized power dispatch for multi-stack HE plants

Develop an optimized power allocation method using the two main power dispatch strategies

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Ensure all stacks operate within their **high efficiency region** under varying input power

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Modeling of the control algorithm of the allocation strategy in EMT simulation platform

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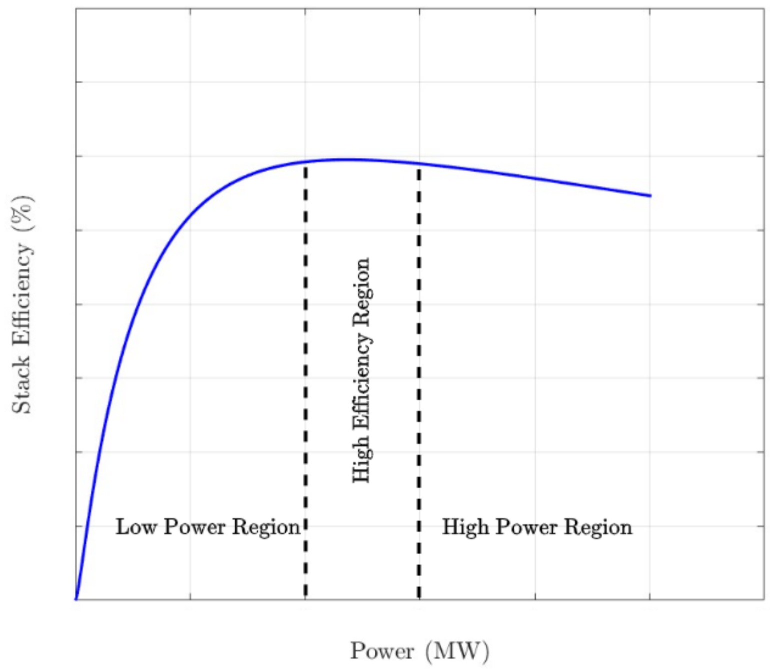
Conduct comprehensive test cases to evaluate and analyse the impact on dynamic power system studies



Future Work

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2. Fault ride-through capability of scaled-up HE plants

Identify the latest grid-code requirements for fault ride-through from large loads

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Develop a system-level scaled-up HE model and particular control strategies

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Analyze the possible solutions to improve the FRT capability of scaled-up HE plants

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Simulate test cases under various voltage disturbances to observe the FRT capability of scaled-up multi-stack HE plant

Thank You!