Test protocols for accelerated in situ degradation of alkaline water electrolysis under dynamic operation conditions

elyntegration

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Outline

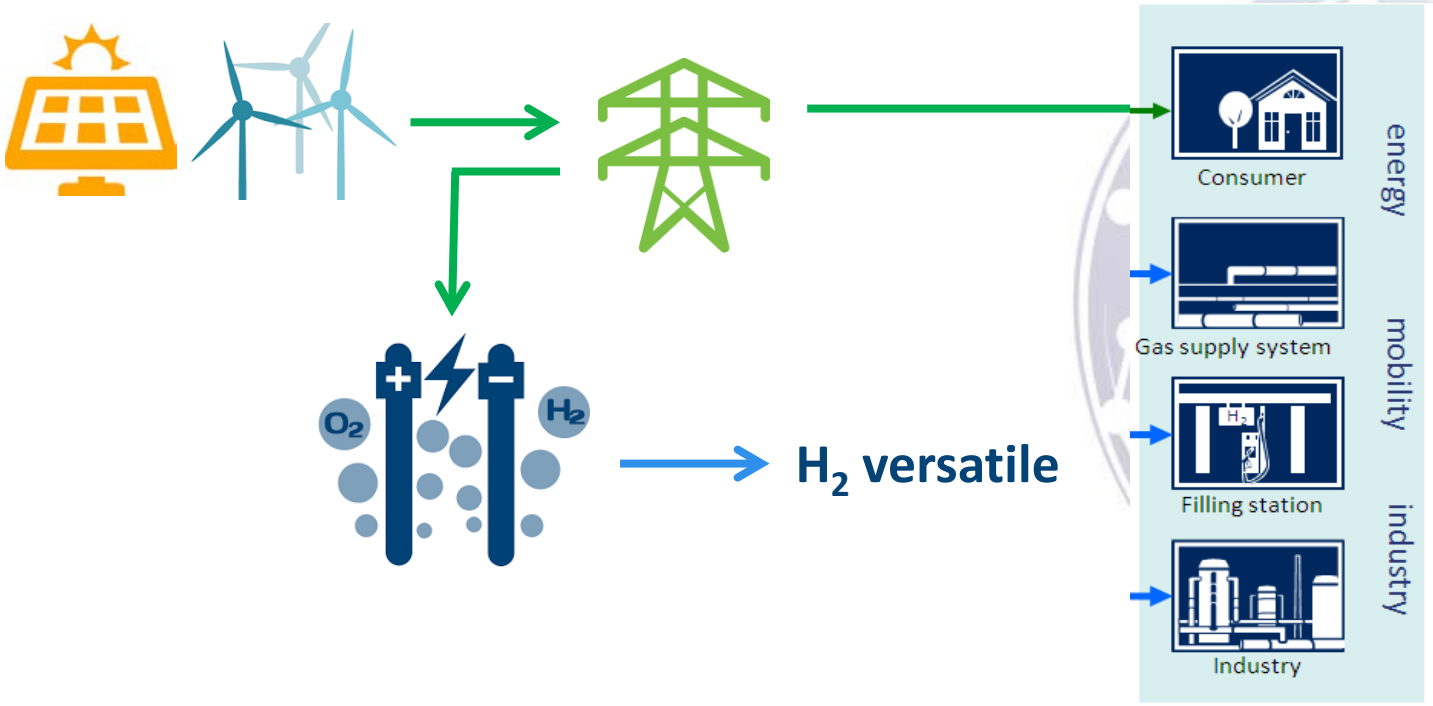
- Motivation, challenges and objectives
- Why do we want to have accelerated stress tests (ASTs)?
- Design of testing protocols
- Methodology
- Results
  - Electrochemical characterization on steady conditions
  - 60 days performance under high dynamic conditions
  - Lifetime providing grid services
- Conclusions

The role of water electrolysis in a decarbonized energy market

Increasing share of intermittent renewables especially in the electricity mix

Key potential benefits resulting in overall reduced cost of production for green H_2

- Optimal use of renewable energy electricity (H_2 production from excess REs)
- To stabilize the electricity grid (additional revenue stream for green H_2)



Key challenges & Objectives

➢ **Perfomance**
(higher efficiencies → lower OPEX → higher allowable electricity prices, load flexibility)

➢ **Cost competitiveness**

Alkaline water electrolysis potential for operating under high dynamic conditions

- Cell design and improvements at stack level

  →high performance in a broad range of the electrolyzer load

  – New material development (electrodes , **membranes**)
  – Topology and assembly of the final stack solutions

- Definition and design of an optimized balance of plant (BoP)

  – Analysis of the BoP components and streams which could derive in lower costs of the system
  – Participation of industrial and technological partners

Material: new separator membrane

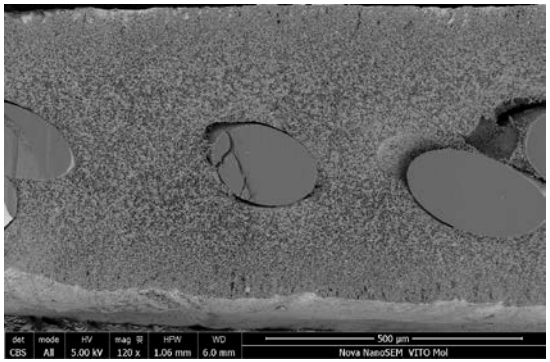
- Highly porous, compressible separator membrane
  - low ionic resistance
  - gas tightness thanks to compression in the electrochemical cell

Separator in un-compressed form

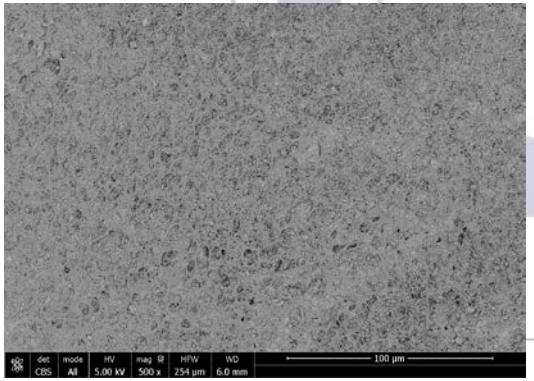
Separator compressed in the cell to ~80% of its original thickness

- Mixed matrix (organic-anorganic) composite membrane.
- Textile reinforcement
- Pore template (60 nm primary grain size)

Cross-section of a compressible separator



Top view of a compressible separator



Why do we need accelerated stress tests (ASTs)?

- Degradation occurs slowly → investigation of long term durability = **€€€**

- Cheaper and more efficient stacks required in broad range of load
  = new materials → unknown behaviour

  → Fast screening of these new materials by low cost method

How do we approach AST development?

Which are the stressors?

Design of AST protocols

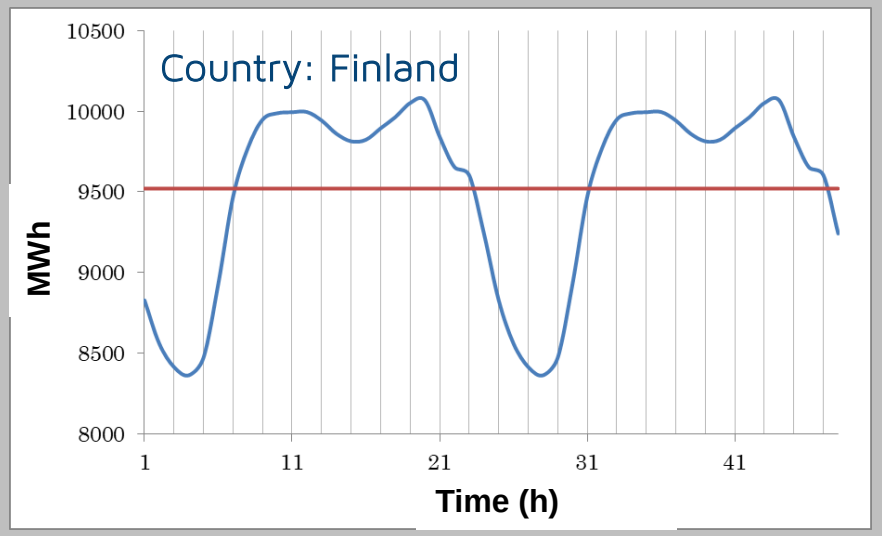
Stressors defined by operating conditions:

- **Grid service**
- Power of electrolyzer (minimum/maximum)
- Operating conditions (T, P, KOH flow, ...)

Service constraints:

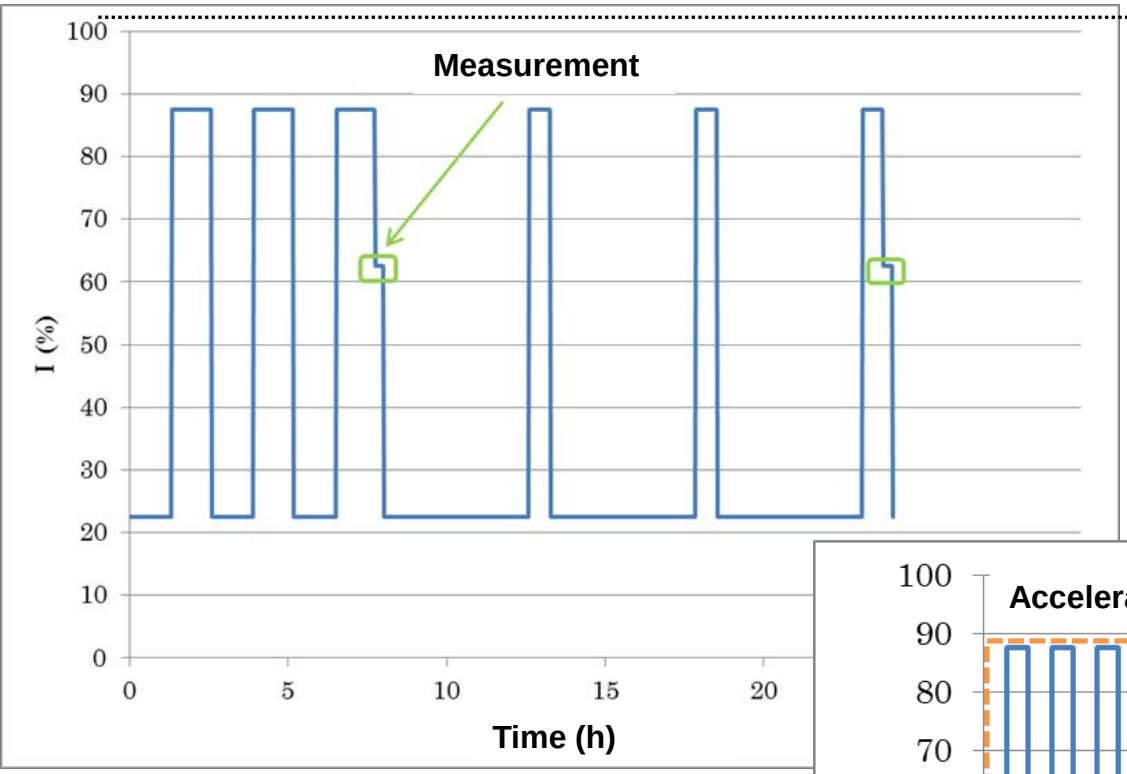
- symmetrical or separated bids
- minimum bid size (5 MW)
- response time (2 mins)
- tender period (annual)
- times triggered per tender

  (several times per day)

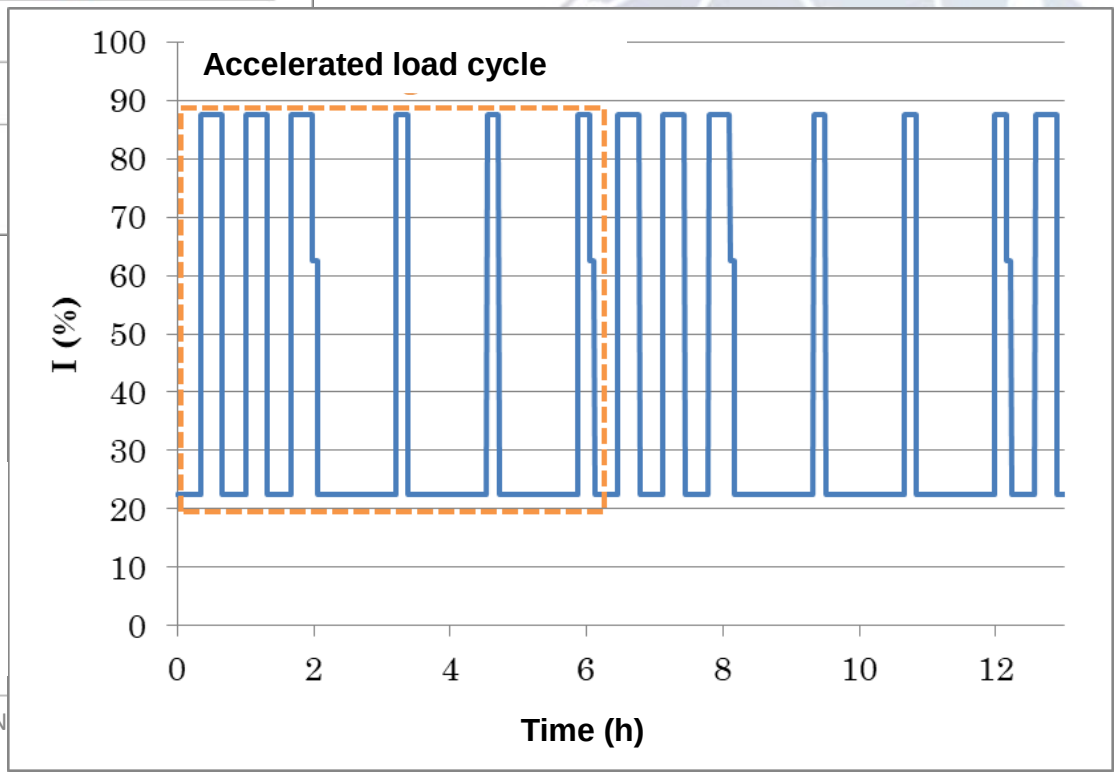


Mapping Demand Response in Europe

Design of AST protocols



- Grid service: case for Finland
- Partial load (maximum/minimum)
- Fixed conditions: Temperature, Pressure, KOH flow

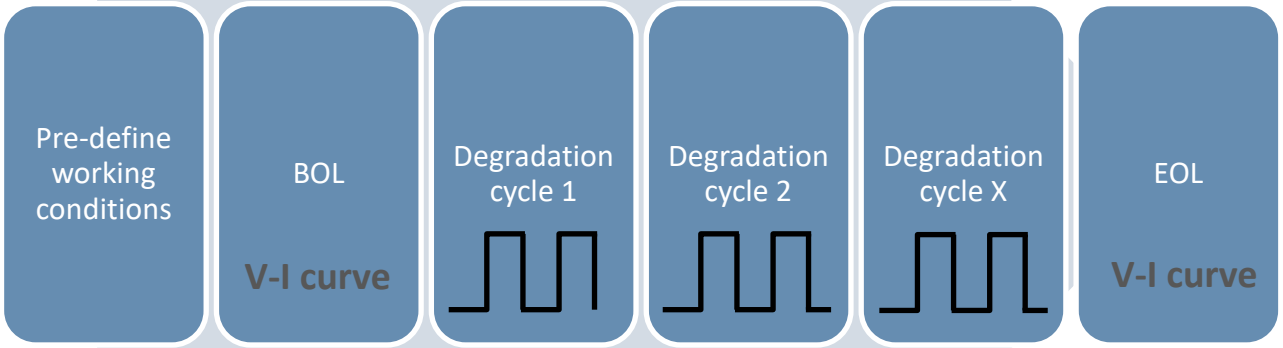


Methodology: test bench and AST protocol

Characteristics:

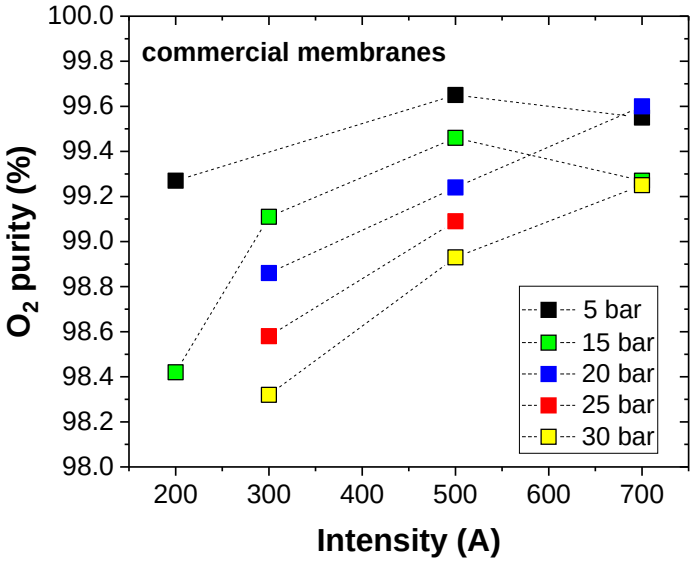
- pressure: up to 60 bar
- power: up to 25 kW
- temperature: up to 95 C
- hydrogen production: up to 3.5 Nm3/h
- monitorized by control remote
- ATEX components and instrumentation

Test bench facilities at FHa



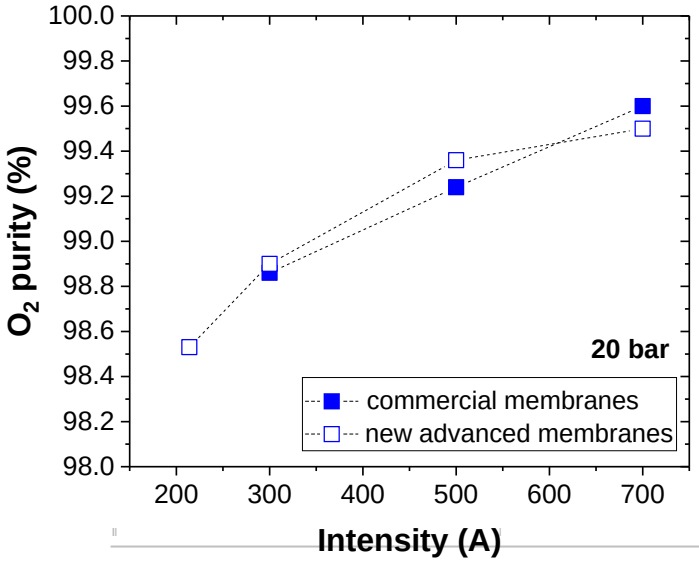
Advanced stack: new membranes, 10 kW power

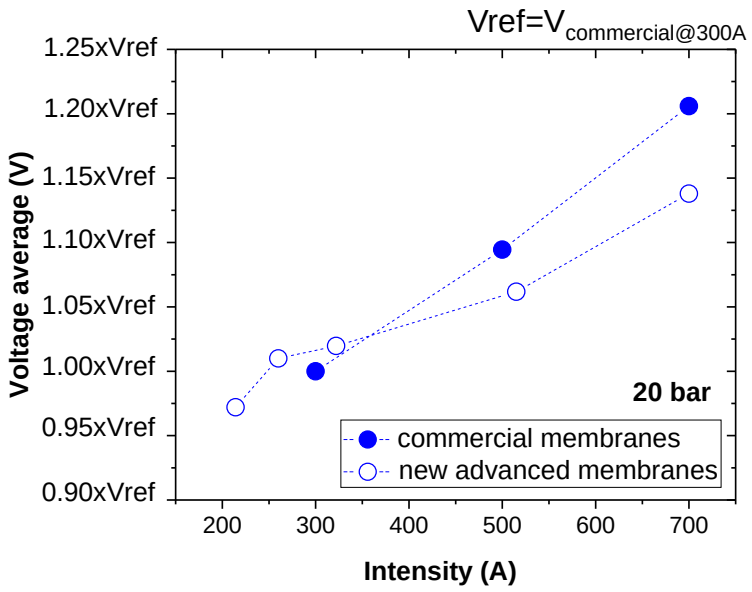
Results: Electrochemical characterization



→ Gas purities good enough at low partial loads and high pressure

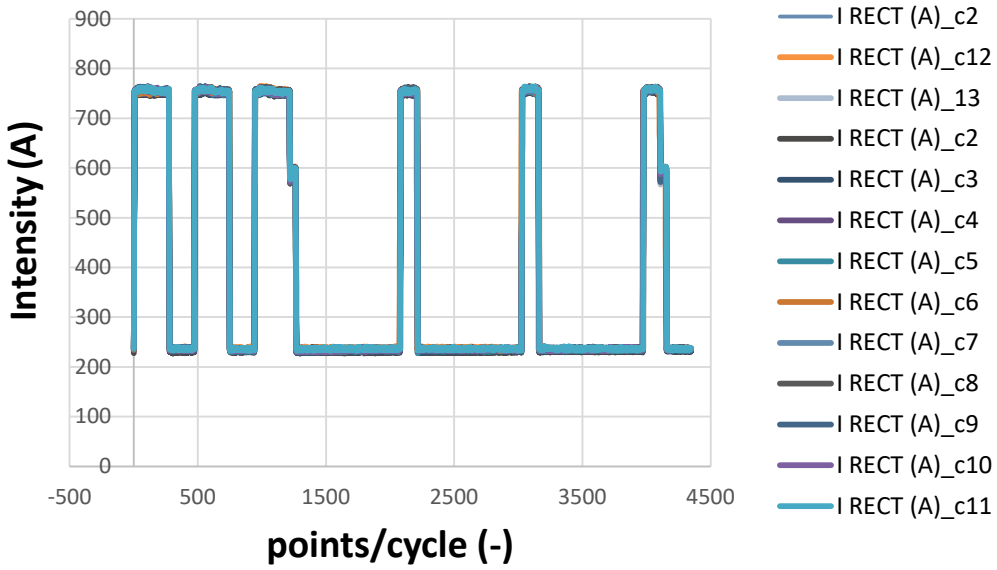
→ Low ionic resistance

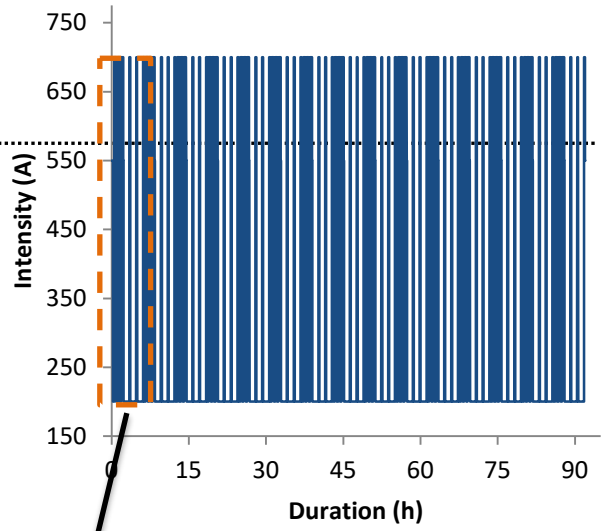


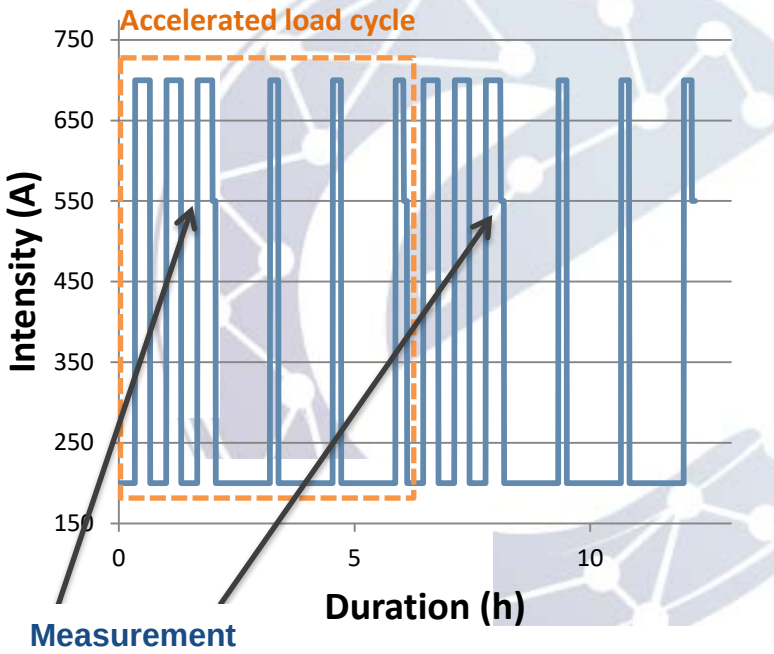


ASTs: 60 days degradation

Current stability along cycles





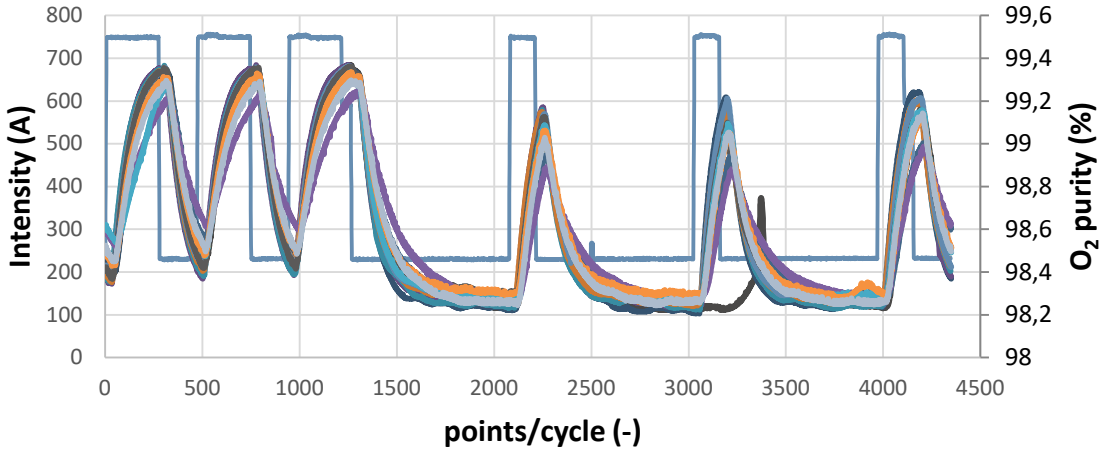


Advanced alkaline water electrolyser stack:

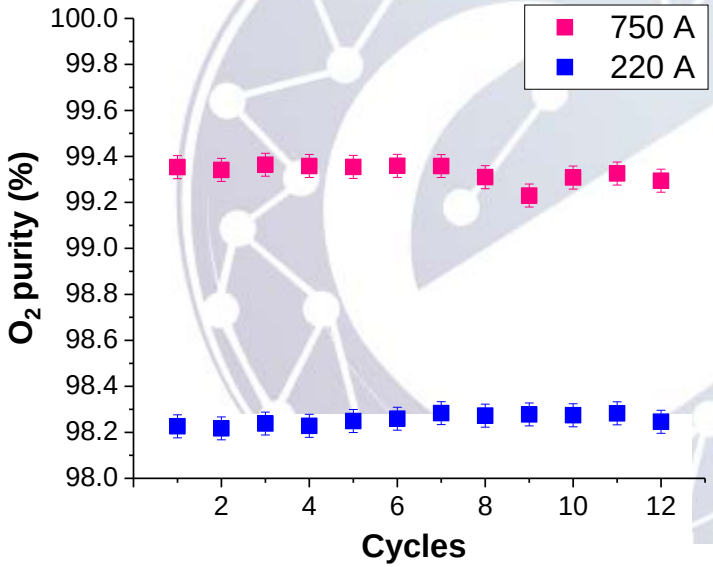
- ✓ new membranes
- ✓ 10 kW power

ASTs: 60 days degradation under high dynamic profiles

Effect of ASTs cycles on the gas purities

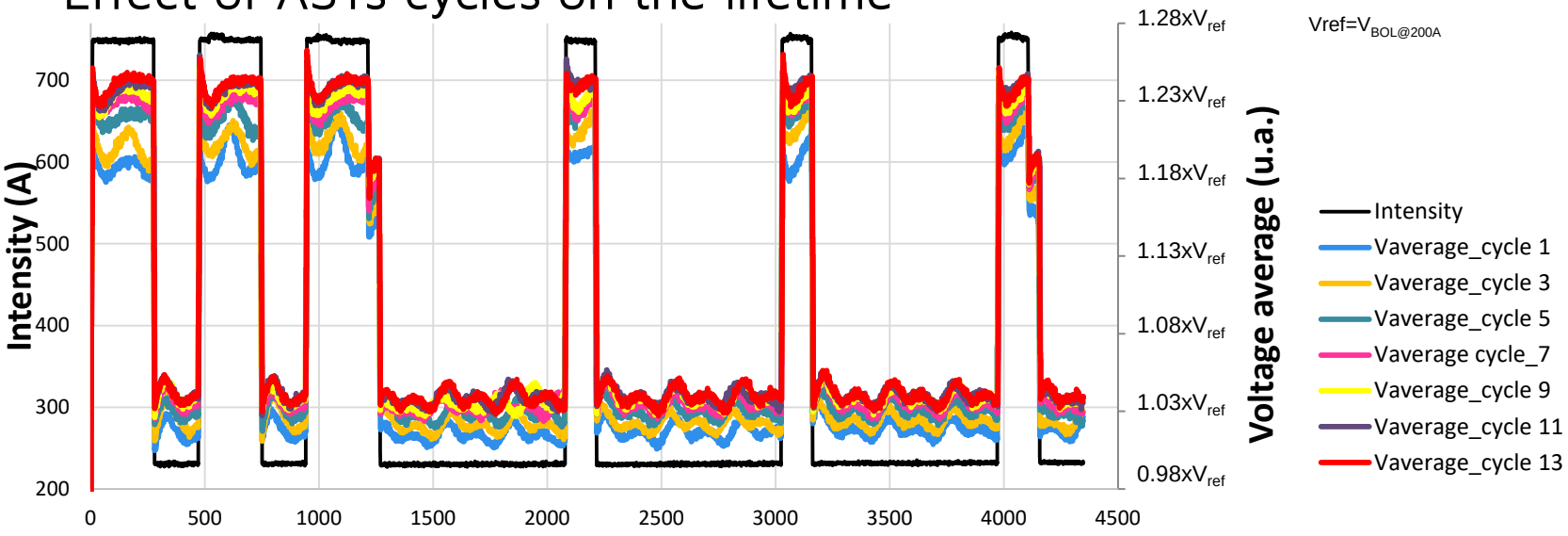


O_2 purity (%)	O_2 purity (%)	Intensity (A)
BOL	EOL	
98.32	**98.25**	220
99.63	**99.51**	750

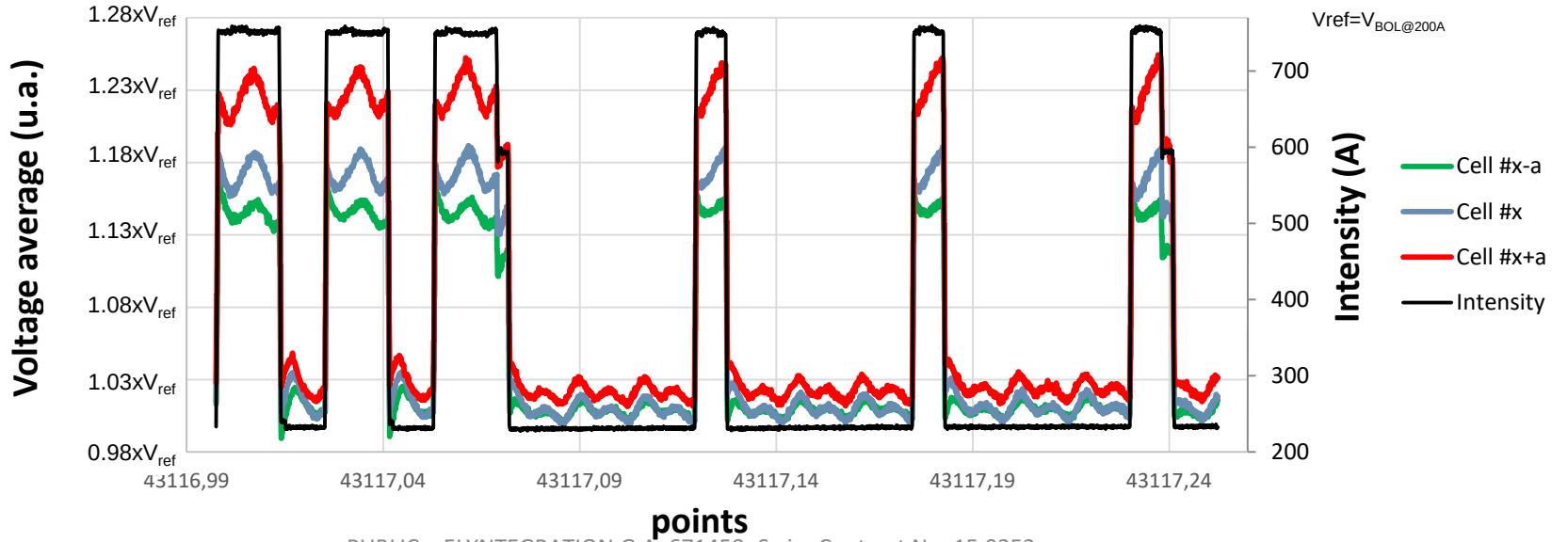


ASTs: 60 days degradation under high dynamic profiles

Effect of ASTs cycles on the lifetime

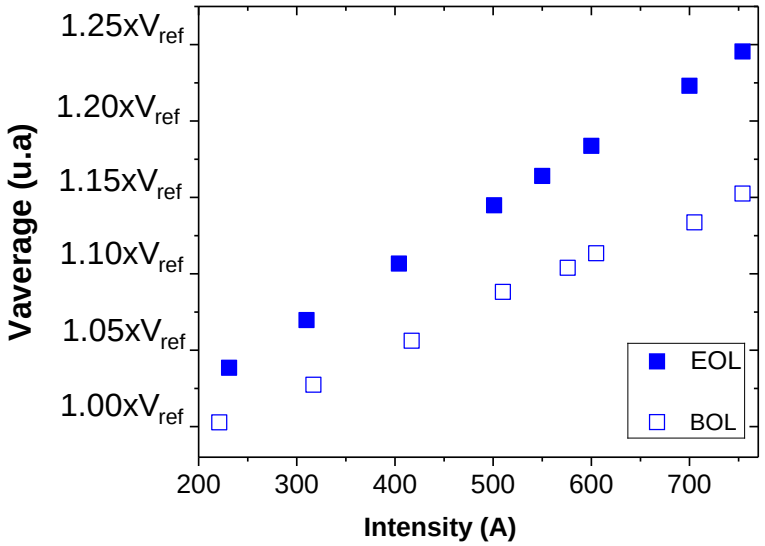


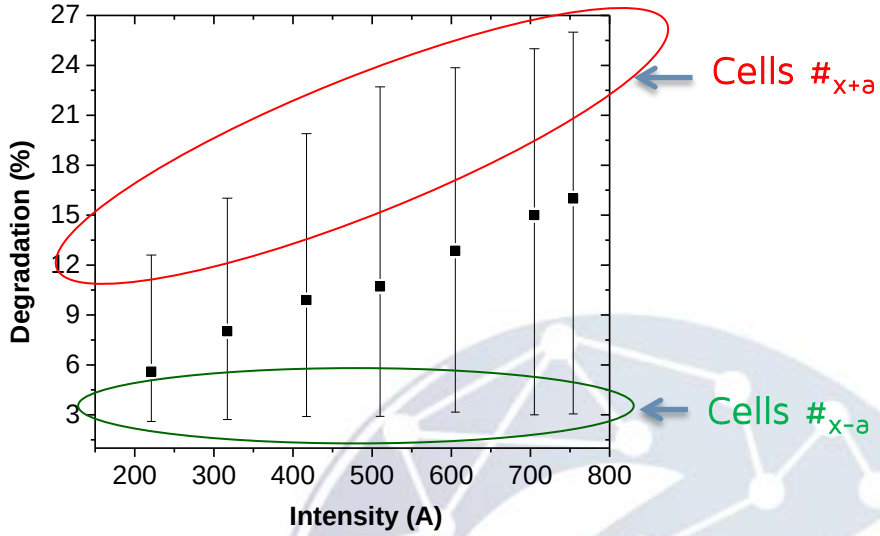
Voltage trend as a function of #cell for a fixed cycle



Durability under high dynamic conditions

Vref=$V_{BOL@200A}$





- Alkaline water electrolyzer providing grid services:
  - release of power, 5MW
  - response time in 2 mins
  - several times per day

Conclusions

- New compressible separator membrane developed:
  - gas cross-over reduction: HTO 13% lower than with commercial ones.
  - cell potential similar to commercial membranes.

- Accelerated durability tests as a tool to observe the effect of dynamic partial load on electrolyzer performance.

- During 60 days of dynamic operation:
  - Some cells present a sharp increase in the voltage degradation rate
  - Some cells the voltage degradation goes down to 3%.
  -

- Gas cross-over contamination is not affected by the dynamic conditions. Gas purities at high and low current densities at 25 bar are constant after 60 days providing grid services (case of study: Finland).

Acknowledgement

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