Towards solid oxide electrolysis plants in 2020

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Towards solid oxide electrolysis plants in 2020

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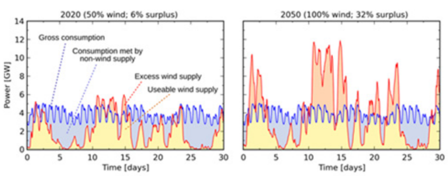
Nøgletal

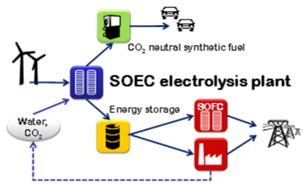
Period:	2015 - 2017	
Funding year:	2015	
Own financial contribution:	3.28 mio. DKK	
Grant:	15.45 mio. DKK	
Funding rate:	82%	
Project budget:	18.73 mio. DKK	
	ForskEL	Internal
➢ DTU Energy	10.22	1.14
➢ Haldor Topsoe A/S	1.76	1.76
➢ Aalborg University	1.59	0.18
➢ DTU Elektro	1.88	0.21

Projektbeskrivelse/formål/målsætninger

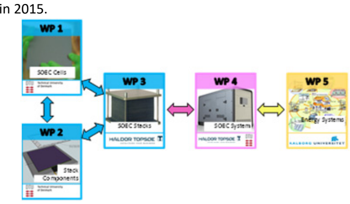
The goal of the project is to further improve performance and durability of solid oxide electrolysis cells (SOECs) and stacks targeting applications specifically for regulating the future Danish power system with a high amount of fluctuating renewable energies, and at the same time enhance the cost competitiveness and environmental friendliness of the SOEC technology, with an ultimate goal of making the SOEC technology ready as a key player in the transition to renewable energy available from around 2020. The current project is based on the previous line of SOEC-focused ForskEL projects (ForskEL 10609 "Development of SOEC cells and stacks" and ForskEL 12013 "Solid oxide electrolysis for grid balancing"), of which ForskEL 12013 was awarded with the ForskEL award as the best finalized ForskEL project in 2015.



Denmark's ambitious plan to rapidly increase the fraction of renewable energy supply towards 100 % over the coming 35 years will lead to huge changes in the electricity grid and a need for large-scale energy storage due to the intermittent nature of wind and solar power.



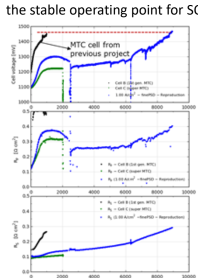
SOEC is a unique energy conversion technology that can provide regulating services to the electrical power grid by efficient storage of electrical energy as fuels. The fuels can be converted back to electricity by running the SOEC in the reverse power generation mode.



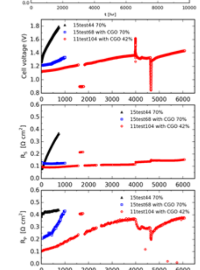
The project is structured into five technical work packages (WPs). WPs 1-4 focus on the SOEC technology development, covering from SOEC cells, stack components, to stacks and systems, while WP5 provides analysis on energy system level and gives inputs to WPs 1-4.

Fremskridt/resultater

DTU Energy improved performance and durability of SOEC cells and stack components. Stable electrolysis operation at -1 A/cm² has been demonstrated **for more than one year** with the 2014 generation SOEC cells. By introducing electro-catalysts into the Ni/YSZ electrode, the stable operating point for SOEC cells was pushed to -1.25 A/cm².

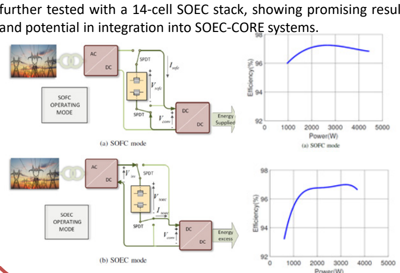


One-year SOEC single cell test under -1 A/cm² at 800 °C conducted in the current project (blue curve).

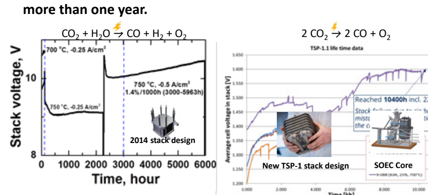


*Long-term steam electrolysis durability tests **under -1.25 A/cm²** at 800 °C. The cell degradation was reduced by a factor of 15, from 714 mV/1000h (black curve) to 50 mV/1000h (red curve).*

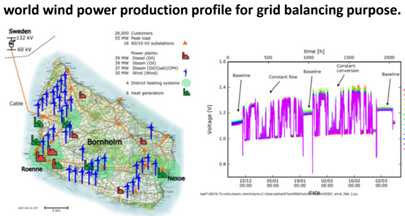
DTU Elektro developed **a novel reversible AC-DC power supply unit (power converter)** for SOEC/SOFC reversible operation, demonstrating **a maximum efficiency of 96.5 %**. Its control was further tested with a 14-cell SOEC stack, showing promising results and potential in integration into SOEC-CORE systems.



HTAS focused on SOEC stacks and SOEC-CORE systems. A 6000 h long-term co-electrolysis stack test was completed (in collaboration with DTU Energy), demonstrating feasibility of SOEC for syngas production. Improved stack performance and durability was demonstrated by incorporating newly developed stack components or by improved stack design (TSP-1), with **actual demonstration for more than one year.**



It has also been demonstrated that **large SOEC stacks (TSP-1, 75 cell, rated power 7.5 kW) can be operated in a stable manner with a real world wind power production profile for grid balancing purpose.**

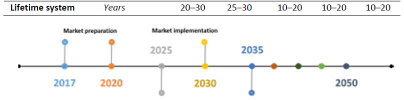


Left: Illustration of the Bornholm power distribution system. Right: Acutal stack test based on 100 % absorption of the wind power.

AAU analyzed the role of electrolysers on electricity markets towards 2020 and 2035 in an international energy market context, focusing on alkaline electrolysis and SOEC. **A Danish roadmap for large scale implementation of electrolysers for the period 2020-2035 was established.**

Cost data for alkaline and SOEC electrolysers (2012 prices).

		Alkaline		SOEC		
		2012	**2020–2030**	**2020**	**2030**	**2050**
Investment costs	*M€/MW*	1.07[5]	0.87[3,6]	0.93[7]	0.35[4]	0.28[4]
Fixed O&M costs	*% of inv./year*	4	4	3	3	3
Variable O&M costs	*€/MWh*	-	-	-	-	-
Lifetime stack	*Operating hours*		<90,000	<90,000	<90,000	<90,000
Lifetime system	*Years*	20–30	25–30	10–20	10–20	10–20



Roadmap for electrolysis systems from now to 2050.

Næste skridt

A number of good results on the SOEC technology development have been achieved in the current project.

- ➢ Some of them have already been implemented in the SOEC production at HTAS, such as the improved SOEC stack and SOEC-CORE designs.
- ➢ The results obtained by DTU Energy, in particular improvements in performance and durability of cells and stack components, improved understanding of degradation mechanisms, and fruitful degradation mitigation strategies will be transferred to HTAS.
- ➢ The power converters developed by DTU Elektro will be transferred to companies specialized in this area.

The results obtained in the series of ForskEL projects including the current project played a key role in achieving the development targets necessary for commercialization of the Danish SOEC technology.

Konklusioner og Perspektivering

As compared to the previous projects, significant progresses have been achieved in this project with respect to the SOEC technology development.

- ➢ With the 2014 generation technology, **we have demonstrated stable electrolysis operation for more than one year**, both at the cell level and at the stack level.
- ➢ We have also shown that **the cells and stacks can be operated in a stable manner under grid balancing related conditions, with a realistic wind power production profile.**
- ➢ By introducing electrocatalysts into the Ni/YSZ electrode, **we were able to push the operating point for SOEC cells from -1 to -1.25 A/cm²** with on-going cell tests running for more than 6000 h.
- ➢ At the stack level, we have further improved the gas flow distribution and the interface adherence and the new stack design is now implemented in HTAS stack production.

The results obtained in this project are in line with the Danish national strategy and roadmap on SOEC and has further contributed to the commercialization of the SOEC technology at HTAS.

Along with this series of ForskEL projects, **HTAS has now maturized its on-site carbon monoxide generation technology (based on electrolysis of CO_2) to a small-plant level.** This achievement is an important stepstone in commercialization of the SOEC technology, towards the final goal of making it ready as a key player in the transition to renewable energy available from around 2020.