Towards solid oxide electrolysis plants in 2020

Chen, Ming; Blennow, Peter; Mathiesen, Brian Vad; Zhang, Zhe

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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 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 2050 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. In this context, electrolysis is perceived as one of the key technologies for the future, being able to store electrical energy as chemical energy in the form of fuels and be later reconverted to electrical energy. 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.

Some of these benefits are due to the unique design of the SOEC, which involves a solid electrolyte and a solid electrode, allowing for lower cell overpotentials and higher operating temperatures compared to conventional electrolytic processes. The high operating temperature also enables the use of high-temperature materials, which can have improved durability and performance over traditional low-temperature electrolysis technologies.

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

Fremkridt/resultater

DTU Energy improved performance and durability of SOEC cells and stack components. Stable electrolysis operation at $1.25 \text{ A/cm}^2$ 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 $1.25 \text{ A/cm}^2$. The cell degradation was reduced by a factor of 15, from 714 mV/1000h (red curve) to 50 mV/1000h (red curve). 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.

Long-term steam electrolysis durability tests under $2.25 \text{ A/cm}^2$ at $800 ^\circ\text{C}$. 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 for integration into SOEC-CORE systems.

NTA 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.

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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 TASA, 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 faulted degradation mitigation strategies will be transferred to TASA. 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.

Denmark’s ambitious plan to rapidly increase the fraction of renewable energy supply towards 2050 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. In this context, electrolysis is perceived as one of the key technologies for the future, being able to store electrical energy as chemical energy in the form of fuels and be later reconverted to electrical energy by running the SOEC in the reverse power generation mode.

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

1. 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.
2. 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.
3. By introducing electro-catalysts into the Ni/YSZ electrode, we were able to push the operating point for SOEC cells from $1$ to $1.25 \text{ A/cm}^2$ with on-going cell tests running for more than 6000 h.
4. 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 commercialisation of the Danish SOEC technology at HTAS.

Along with this series of ForskEL projects, HTAS has now matured its on-site carbon monoxide generation technology (based on electrolysis of $\text{CO}_2$) to a small-plant level. This achievement is an important step in commercialising 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.