Efficient and Cost-Effective Hydrogen Production for Decarbonation

Modeling, Enablement and Validation of Prognostics and Health Management Solutions for Solid Oxide Electrolysis

Background Information – Key Drivers

To efficiently produce high volumes of green H2, at economically compelling costs, the use of advanced technology components such as Solid Oxide Cells (SOC) and subsequent stacks, as core technology for large scale industrial systems, is an ambitious but credible path – supported by France and Europe given obvious decarbonation and industrialization benefits[1].

Outstanding technical progress has been made over the last 15+ years to understand and improve the performance and durability of SOC based technology and components. Understanding the physics of failures and degradation mechanisms, combining modeling and experimental work have translated into significant design, materials and process improvements over time but remain key R&D focus areas still. Indeed, multi-stack based SOC solutions must operate at very high temperatures (between 700 to 800 deg. C) for many years with minimum and controlled degradation of their overall performance.

Intrinsic performance degradation over time and potential failures impacting industrial processes go hand in hand with needs to enable and develop sensible Prognostics and Health Monitoring (PHM), derived Condition-Based Maintenance (CBM), as a way to reduce the Total Cost of Ownership (TCO) safely and efficiently produce hydrogen for various industrial applications aiming for decarbonation.

Performing PHM in High Temperature Electrolyzer Modules is still an open field of applied research, with no solutions to allow HT Electrolyzer to be used widely in society. The very high temperature of operation forbids many types of direct measurements on the stacks; highly expensive sensors per cell or per stack would render the technology commercially unviable; models to predict degradation are still unreliable as the technology is relatively new.

Work Description

The first part of the PhD work will consist of understanding the operation of SOC technology and its use for industrial applications, gathering information about existing SO cells & stacks models and potential monitoring solutions. The PhD candidate will benefit from access to prior art, legacy and ongoing R&D work done by CEA teams/resources. She/he will also interact with the Genvia/CEA systems engineering/R&D teams in charge of developing High Temperature Electrolysis (HTE) modules for industrial demonstrators.

[1] https://insight-project.eu

Indeed, the development of effective PHM and derived CBM solutions requires the development and use of hybrid models combining relevant physics and measurements/data. There are several aspects that go hand-in-hand for this research:

1. The development of physics-based models of relevant components of the system, capable of providing relevant information about the state of the system and potential degradation phenomena, considering the model complexity (model reduction and simplification) and its use for diagnostic and optimization (control/optimization-oriented models)
2. The design and choice of elements to serve as direct measurement, indirect measurement, and canary; these can be designed/chosen based on models and/or the understanding of the stack and module and/or experiments with prototypes
3. The refinement of the models, developed in point 1, by exploiting available measurement information (data). The main objective of this point is to identify relevant parameters of the physics-based models, as well as potentially construct simple behavioral models for subsystems for which these models are not available or too complex.
4. System parameters optimization against given H2 production rate scenarios: Tracking of internal states and parameters and apply prediction algorithms (to be developed and based to point 3) to estimate remaining time before maintenance

One particular challenge is to explore and define, through collaboration work, design provisions for "passive elements" that could be added to the cells or stacks to assist with their location identification and performance monitoring, enable indirect measurements of key parameters such as temperature, voltage, currents or even pressure profiles with a resolution at the stack, ideally cell level. Such indirect measurements, assisted by design provisions, can be done permanently from outside the hot zone and/or through periodic inspection of the hot zone by metrology means under development. The provision for including passive elements into the design should also consider the possibility of adding elements with known degradation over time, i.e. so-called canaries, matching typical degradation of core elements which are present in high number and difficult to monitor individually.

In addition to theoretical/analytical work, we foresee opportunities for the PhD candidate to build prototypes and perform lab experiments as needed.

<u>Candidate skills and knowledge required</u>

Strong physics and (applied) mathematics background. Systems engineering, automation and control (parameter identification, control, optimization, etc.).

One (or both) of the following backgrounds:

- Analytical and numerical modeling skills (physics and applied mathematics)
- Modeling, signal processing, inversion (via mechanical/materials engineering or electrical engineering curriculums)

Experience/interest in experimental work, or experience/interest in close collaboration with colleagues in experimental work. Highly motivated to bridging the gap between theoretical concepts and practical engineering applications.

Knowledge of electrochemistry would be an advantage.

Diplôme Grande école or University with relevant degrees.

Workplace

CEA/DRT/LITEN, Grenoble - France (Main location). INSA Lyon, Laboratoire Ampère (Secondary location, frequent visits).

Short duration trips in France to interact with various team members from various locations, e.g. Clamart, Saclay, Bruyères-le-Châtel, are to be expected.

PhD Support Team

INSA Lyon, Laboratoire Ampère

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Duration and remuneration

- 3 years starting October/November 2022, depending on administrative formalities.
- Remuneration: 30,000€/year gross salary

If interested, please send your CV and motivation letter to all above email recipients.

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