Modelling and experimental investigation of a reversible solid oxide stack using advanced State-of-Health online monitoring tools.

Supervisors: Prof. Jan Van herle (jan.vanherle@epfl.ch); Dr. Hamza Moussaoui (hamza.moussaoui@epfl.ch)

Context

Thanks to their high efficiency, large fuel flexibility, and reversibility between fuel cell and electrolysis operations, Solid Oxide Cells (SOC) have great potential for becoming a key technology in the ongoing energy transition. Indeed, the same device can alternatingly be used to produce hydrogen/methane from excess green energy, and *vice-versa*, power and heat from hydrogen/methane, when and where they are needed. Besides, thanks to its low cost (no expensive catalysts like platinum are required), and customizable power (cells are stacked to reach any target), reversible SOC can be the answer for a very wide range of applications from residential and industrial to transportation sectors.

Nevertheless, durability remains the main impediment towards the large-scale deployment of these electrochemical conversion devices. Statistical on-field operation data reveal that the lifespan of SOC systems can considerably be extended with optimal operation of the system. Intrinsic material degradation is then not the most limiting obstacle towards reaching the 40'000-h-target system lifetime (green curve in Figure 1), but rather faulty conditions that occur due to components failure. Indeed, a problem in the gas supply, the gas cleaning devices, or sensors can lead to irreversible degradation of the stack or even cause its end of life (c.f. scenarios 1 and 2 in Figure 1). The early detection and identification of faults are of central importance to act timely and minimize any damage by applying relevant mitigation and recovery strategies (scenarios 3 and 4 in Figure 1). Precise and non-disruptive online monitoring of the system's state-of-health is then essential towards reliable SOC systems.

Objectives

The current work falls within this framework and aims at experimentally testing a 6-cell short stack from a commercial partner. Advanced online monitoring tools, like Total Harmonic Distortion Analysis (THDA), and Electrochemical Impedance spectroscopy (EIS) [1] will be used to evaluate the stack state-of-health. First, a performance mapping will be done by operating the stack in normal (non-faulty) conditions. Then, on-purpose faults will be introduced to simulate the most frequent failures that may occur in the system. For example, fuel starvation can be triggered to simulate an error in the fuel supply circuit, or high steam conversion in the case of an interruption of the steam generation module. The objective of this experimental section is to identify the failures footprint for an early detection and identification purpose.

A second modelling part consists in simulating the electrochemical behavior of the stack by using and adapting an in-house Matlab® model. This will support the interpretation of the experimental results by providing, for example, local properties that cannot be measured experimentally. The model should also help linking the cell's answer to the operating conditions, including the faulty ones. Finally, this coupled experimental and modelling approach would help achieve a clearer understanding of the stack behavior to faulty conditions and provide relevant guidelines towards optimal system operation.

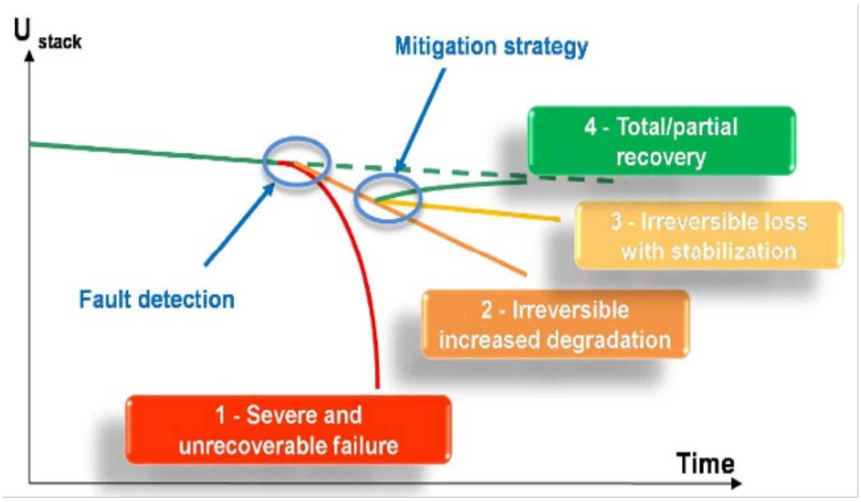

Figure 1: Schematic representation of voltage evolution over time and the different cases that can be encountered by the cell depending on the nature of the fault and the mitigation strategy. The green curve depicts the intrinsic cell voltage degradation, while the other colours refer to the additional degradation due to an extrinsic failure.

[1] P. Caliandro, J. Van herle, S. Diethelm, Published in Infoscience.epfl, 2018. doi: 10.5075/epfl-thesis-8389.