Project name: Electrolysers' ageing, diagnosis and prognostic for hydrogen production (VieElecH2)

Apply for: PhD thesis of 3 years

Location: University of Caen-Normandie, LUSAC laboratory

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Subject, context and objectives

Nowadays hydrogen is considered as an essential energy vector in the energy transition. To enhance efficiency and, in particular, the utilisation ratio, recovering energy overproduction is the main challenge. The electrolyser (EL) is the key to this strategy, converting electrical energy into hydrogen and heat, which can also be recovered for cogeneration. If today the market is ready to absorb the new technology to achieve large-scale deployment and lower system costs, the lifetime of ELs remains a technical barrier. Indeed, the performance of ELs can vary depending on the operating conditions. Several degradation mechanisms can take place in case of prolonged operations under stress conditions. It is worth noting that to date, research projects focus more on modelling EL applications in a microgrid. While, the integration of ageing variables represents, to date, the major challenge and the gap to be filled.

The proposed thesis combines the LUSAC experience in the fields of energy management and storage and hydrogen production based on renewable energies. The thesis aims to promote the study of the electrolysers (EL) operations in nominal, failure, and degraded modes. The objective is to characterize, model, and predict the electrolyser's behaviour (in terms of performance) during start-stop (intermittent) conditions, its operation at a nominal point, and under dynamic power profile. System ageing will be studied to assess performance losses and predict its lifespan. This will enable the development of diagnosis and prognostic strategies. The main objective is the development of a generic procedure dedicated to both research and industrial needs for EL lifespan enhancement.

The LUSAC laboratory has experience in several European and French projects; among others, the European Interreg projects ITEG and NS H2V Ports for the production of H_2 from renewable energy and the creation of a port network (in the North Sea Area) for the production, use and distribution of H_2; finally, the AMI CMA H_2 CARBON neutrality project of the Call for Expressions of Interest "Skills and Professions of the Future", 2nd wave, France 2030, to develop and promote the decarbonized hydrogen training sector. Moreover, the LUSAC laboratory received funding for an experimental platform to study hydrogen production and uses from renewable energies (particularly marine renewable energies). The platform's equipment allows to study, develop and validate different scenarios for the production of hydrogen from renewable energies, its storage, and uses. The durability of both fuel cell and electrolysers devices are then analysed under real working conditions. Concerning storage devices, two different technologies (pressurised gas and solid form) are considered. Finally, a new module is planned to study the impact of sea air, particularly salinity levels, on the energy performance and ageing of H_2 technologies. In addition to the platform, an electrical microgrid is used to emulate both the electrical production (sources), needs (loads), and storage.

This thesis proposes to enhance the current H_2 platform with an EL ageing test bench module, by defining test and ageing protocols and data analysis. Generic procedures capable of linking experimental activity to ageing caused by real-world applications are investigated. Test campaigns under nominal operations and stress conditions will be implemented, for the ageing characterization. Among the various accelerated stress factors, both the power variations (dynamics), the start-stop repetitions, and the thermal and chemical stress (marine environment and salinity level) are considered. Subsequently data are stored and analysed for developing electrolyser diagnostic and prognostic methodologies. To achieve this, we first compare existing methods and select the most relevant ones for application to electrolysers. Particular attention will be paid to Artificial Intelligence (AI) approaches. The goal is to establish a fast, reliable, and less data-intensive methodology to evaluate the current state of health of the EL and the remaining useful life.