utbm université de technologie Belfort-Montbéliard

UBFC UNIVERSITÉ BOURGOGNE FRANCHE-COMTÉ

école doctorale **sciences pour l'ingénieur et microtechniques** SPIM

Thesis title : Multiphysics modeling and characterization of alkaline and PEM electrolysers for the optimization of green hydrogen production.

Host Laboratory : FEMTO-ST/ENERGIE

Speciality : Engineering science

Keywords : Wind and photovoltaic energies, alkaline electrolyser, PEM electrolyser, power electronics, optimal design, control, energy management, multi-physics modeling (electrokinetics, thermofluidics)

Job description

Alkaline electrolysers represent a mature technology, widely used at present for the production of green hydrogen. Compared to PEM electrolysers (proton exchange membranes), alkaline electrolysers allow a lower current density (0.4A compared to 2A), a lower energy efficiency and a more complex fluidic circuit. However, their use is still relevant thanks to their durability and low cost. Each technology therefore has advantages and disadvantages which must be studied rigorously for coupling with intermittent renewable energies (RE) such as urban wind and solar photovoltaic, to produce green hydrogen.

In this area, several FEMTO-ST Energy Department projects concerns the creation of a green hydrogen generation demonstrator including photovoltaic panels, a power plant composed of several vertical axis wind turbines as well as two electrolysers (one of the alkaline type and one of the PEM type).

This thesis work aims to optimize this type of hydrogen generator by maximizing its energy efficiency and robustness while minimizing the economic and environmental cost. This involves choosing a power electronics architecture, multi-physical modeling of electrolysers and system components, optimal design, control, digital simulation, and experimental tests. This thesis is structured in 4 work packages following an iterative system design process. This process is applied to the production and testing of a green hydrogen generator from a hybrid wind-photovoltaic power plant coupled with both alkaline and PEM electrolysers.

WP1. Modeling the components of a hydrogen production plant powered by renewable energy sources such as photovoltaics and wind power:
- o Renewable energy source (photovoltaic, wind and the combination of both) taking into account atmospheric conditions and ageing.
- o Alkaline and PEM electrolysers (electro-thermo-fluidic multi-physics, 1D, 2D and 3D multi-scales, consideration of aging, and faults prediction).
- o Hydrogen storage devices (under pressure and by metal hydride).

WP1. Optimal design of the energy conversion chain and energy management with aim to maximize the production of hydrogen (taking into account the hybridization of energy storage batteries – hydrogen under the conditions of availability of resources, production and demand forecasting, fault tolerances and degraded modes).

WP2. Numerical simulation including components simulation and the complete system simulation.

WP3. Experimental analysis: electrolysers characterization; validation of developed models and control algorithms. Energy efficiency measurement and comparative study between the two types of electrolysers. Validate the optimal operation point of the hydrogen generation demonstrator.

Thesis planning:

1) Bibliographic research: M1-M6

2) Components modeling: M3-M18

3) Control algorithms and numerical simulation: M13-M24

4) Experimental tests and calibrations: M18-M30.

5) Writing of the thesis report and defense: M31-M36.

6) Publications (at least 1 journal and 2 conferences): M12-M36

Bibliography

[1] A Mohammadi, G Cirrincione, A Djerdir, D Khaburi, "A novel approach for modeling the internal behavior of a PEMFC by using electrical circuits", International Journal of Hydrogen Energy 43 (25), 11539-11549.

[2] A.Mohammadi, P.Massonnat, A.Djerdir, F.Gao, M.Krishnamurthy, D.Bouquain, D.Khaburi, "Fault Analysis of the PEMFC by using 3D Temperature Fault Sensitive Model for Automotive Applications", International Journal on Energy Conversion, 2014.

[3] Vittorio GUIDA, « Conception et réalisation d'un convertisseur DC/DC à haut rapport de conversion pour électrolyseurs », Thèse doctorat de l'Université Lorraine, 29/09/2020 à Longwy.

[4] Kewei Hu a, Jiakun Fang, Xiaomeng Ai, Danji Huang, Zhiyao Zhong, Xiaobo Yang,Lei Wang « Comparative study of alkaline water electrolysis, proton exchange membrane water electrolysis and solid oxide electrolysis through multiphysics modeling", Applied Energy 312 (2022) 118788

[5] Benjamin Flamm, Christian Peter, Felix N. Büchi, John Lygeros "Electrolyzer modeling and real-time control for optimized production of hydrogen gas" , Applied Energy 281 (2021) 116031

[6] A. Khalilnejad, G.H. Riahy " A hybrid wind-PV system performance investigation for the purpose of maximum hydrogen production and storage using advanced alkaline electrolyzer" , Energy Conversion and Management 80 (2014) 398–406

Applicant profile

The candidate should have solid experience in energy conversion (electrical engineering and/or mechanical engineering), numerical simulation, and experimentation. Adequate knowledge of power system control is also required.

Financement/Funding : MESRI Etablissement/Ministry of Higher Education, Research and Innovation (France)

Application deadline : 20th May 2022
Start of the contract : 1rst October 2022
Gross monthly salary : 1975€

Direction de la these/Thesis Supervisor

DJERDIR Abdesslem/ e-mail : Abdesslem.djerdir@utbm.fr

Encadrement de la thèse/co-supervisors of the thesis :

GIURGEA STEFAN (co-directeur/co-Supervisor): Stefan.giurgea@utbm.fr
SALHI Issam (co-directeur/co-Supervisor) : issam.salhi@utbm.fr

Applicants are invited to submit their application to the PhD supervisors.
Application must contain the following documents:

- CV
- Cover letter
- At least 1 reference letter