Post-Doctoral Position

Fuel Cell Control & Energy Management

1 Context

The LAMIH UMR CNRS 8201 laboratory has a strong history of research in energy management for hybrid vehicles, which combine a conventional engine with one or more electric machines and an electric energy storage system. Previous work includes studies on energy management [1,2], optimal control [3], and implementation optimization [4]. The LAMIH is also internationally recognized for its expertise in the quasi-LPV framework [5, 6, 7].

In the context of the energy transition, we are now exploring even cleaner solutions based on hydrogen. For this post-doctoral position, we propose working on the control and/or energy management of our new fuel cell test bench, funded within the scope of the RITMEA CPER project (see Figure 1).

Figure 1: The Hybrid Fuel Cell test bench available at the LAMIH (Left : fuel cell system. Center: battery pack. Right: schematic)

The test bench consists of a 15-kW fuel cell system and a battery pack connected to a common DC bus. The fuel cell system includes several control loops managing parameters such as humidity, temperature, anode-cathode differential pressure, and others. It is currently operated by a set of single-input single-output (SISO) PID controllers provided by the manufacturer. This control scheme is simple and generally robust; however, sudden load changes should be avoided, as coupling between control loops can result in poor transient dynamics. These PID controllers can be replaced with more advanced control strategies. The controllers for the slower control loops can be implemented on an external dSPACE MicroAutoBox III system, while the faster control loops can be integrated directly into the original ECU code.

Since the fuel cell system is already equipped with a functional set of controllers, it can readily supply energy to the DC bus where the battery pack is connected. As a result, the test bench enables the emulation of a scaled hybrid fuel cell vehicle. The fuel cell power setpoint can be sent via the CAN bus to the ECU, enabling the implementation of energy management algorithms, such as the Equivalent Consumption Minimization Strategy (ECMS).

2 Proposed work

The post-doctoral candidate is expected to work on the low-level control of the fuel cell system OR energy management, depending on their profile and discussions during the interview.

2.1 Low level control

Proton Exchange Membrane Fuel Cell (PEMFC) systems are highly promising for clean power generation in both mobility and stationary applications. However, their strongly coupled multi-physics dynamics—encompassing electrochemical reactions, gas transport, heat, and water management—make them challenging to operate efficiently and durably across varying load conditions.

Conventional control strategies, often designed for decoupled or linearized subsystems, are insufficient to ensure performance and robustness under realistic operating conditions. Therefore, developing nonlinear control and observation strategies capable of managing interacting thermal, pressure, and hydration loops represents a critical scientific and technological challenge. For instance, the air and pressure regulation loop controls cathode pressure and oxygen excess ratio through the compressor and back-pressure valve. Its dynamics are nonlinear and coupled with both thermal and hydration states: airflow affects stack temperature, while pressure influences water vapor transport and membrane hydration. The objective is to develop nonlinear multivariable controllers that ensure fast pressure response and stable oxygen stoichiometry without disrupting the hydration balance.

2.2 Energy Management

Energy management strategies for hybrid powertrains often model the fuel cell system as a power source with static efficiency that depends solely on the load. In practice, however, the dynamic behavior of the fuel cell and its low-level control loops significantly constrains the system’s transient response. Consequently, the effective (dynamic) efficiency also depends on internal system states, such as pressure, temperature, and membrane hydration.

The proposed research aims to characterize these low-level dynamics and incorporate them into an optimal control formulation. The resulting problem will first be solved offline using advanced numerical optimization techniques, such as direct methods, Pontryagin’s Minimum Principle, or Dynamic Programming, to identify optimal operating trajectories.

Based on these results, a real-time energy management algorithm will be developed. Several strategies will be explored, ranging from improved Equivalent Consumption Minimization Strategies (ECMS) to AI-based approaches that generate near-optimal reference trajectories in real time, which will then be tracked by dedicated real-time controllers.

2.3 Outcome

The candidate may work on theoretical aspects of quasi-LPV models (e.g., control, observation, diagnostics, fault-tolerant control) and/or optimal control (e.g., numerical methods) and aim to publish in journals such as IEEE Transactions on Fuzzy Systems, Automatica, or similar. For applications related to the test bench, targeted journals include, for example, Control Engineering Practice, IEEE Transactions on Control Systems Technology, IEEE Transactions on Vehicular Technology, or similar.

3 Candidate profile

Candidates must hold a PhD. We are considering candidates with one of the following two profiles.

- **Control background profile**: The candidate should have a strong background in control theory, with comprehensive knowledge of nonlinear systems, including control, observation, and fault-tolerant strategies. Expertise in advanced control design and analysis is essential. While prior hands-on experience with experimental platforms is not mandatory, **the candidate must demonstrate a clear willingness to apply theoretical developments to real systems and participate in experimental validation on an actual fuel cell test bench**. Knowledge of fuel cell systems or related electrochemical energy conversion technologies will be considered an asset.
- **Fuel cell specialist profile**: The candidate should have prior experience in modeling and controlling fuel cell systems and be familiar with the associated physical and control challenges. Although not a specialist in nonlinear control, the candidate must possess strong practical skills and the ability to implement the technical details necessary to make control strategies operational on real systems. **The postdoctoral work will require a genuine interest in advanced control techniques, and the candidate must be willing to engage with state-of-the-art nonlinear control techniques, particularly quasi-Linear Parameter Varying (quasi-LPV) approaches.**

4 Application

The position is available immediately.

- Supervision: Jointly by A.-T. Nguyen and S. Delprat.
- Monthly Salary: €2,576 gross (approximately €2,100 net) funded by the CPER RITMEA project.
- Location: LAMIH UMR CNRS 8201, Valenciennes, France.
- Application Deadline: November 15, 2025.

Candidates should send their CV, motivation letter, and publication list to: sebastien.delprat@uphf.fr and tnguyen@uphf.fr.

5 Some related references

[1] J. Bernard, S. Delprat, T.-M. Guerra, P. Dietrich, and F. Buechi, “Energy Efficient Power Management Strategy for Fuel Cell Hybrid Vehicles,” International Advanced Mobility Forum, Mar. 2009.

[2] D. Hu, C. Tian, A.-T. Nguyen, and C. Huang, "Uncertainty-driven Active Reinforcement Learning for Energy Management Strategy in Electrified Vehicles. *IEEE Transactions on Transportation Electrification*. 2025, DOI: 10.1109/TTE.2025.3614254.

[3] S. Delprat, T. Hofman, and S. Paganelli, “Hybrid Vehicle Energy Management: Singular Optimal Control,” *IEEE Transactions on Vehicular Technology*, vol. 66, no. 11, pp. 9654–9666, Nov. 2017, doi: 10.1109/TVT.2017.2746181.

[4] C. Armenta, S. Delprat, R. Negenborn, A. Haseltalab, J. Lauber, and M. Dambrine, “Computational Reduction of Optimal Hybrid Vehicle Energy Management,” *IEEE Control Systems Letters*, vol. 6, pp. 25–30, 2022, DOI: 10.1109/LCSYS.2020.3046609.

[5] S. Delprat, J. Álvarez, M. Sánchez, and M. Bernal, “A Tighter Exact Convex Modeling for Improved LMI-Based Nonlinear System Analysis and Design,” *IEEE Transactions on Fuzzy Systems*, vol. 29, no. 9, pp. 2819–2824, Sept. 2021, doi: 10.1109/TFUZZ.2020.3005345.

[6] A.-T. Nguyen, T. Taniguchi, L. Eciolaza, V. Campos, R. Palhares, and M. Sugeno, “Fuzzy Control Systems: Past, Present and Future,” *IEEE Computational Intelligence Magazine*, vol. 14, no. 1, pp. 56–68, Feb. 2019, doi: 10.1109/MCI.2018.2881644.

[7] C. Nguyen, A.-T. Nguyen, and S. Delprat, “Neural-Network-Based Fuzzy Observer with Data-Driven Uncertainty Identification for Vehicle Dynamics Estimation under Extreme Driving Conditions: Theory and Experimental Results,” *IEEE Transactions on Vehicular Technology*, pp. 1–11, 2023, doi: 10.1109/TVT.2023.3249832.