1 General Information

Laboratory	FEMTO_ST
University	University of Technology of Belfort-Montbéliard (UTBM), Univ. Bourgogne Franche-Comte (UBFC)
Contacts	**Thesis advisor: Dr. LAGHROUCHE Salah**
Co-advisor	

2 Thesis title and keywords

Integration of fuel cell based electric and hybrid vehicles as mobile energy storage elements in the "smart grid"

Keywords: Fuel Cell electric vehicles (FCEV), *Energy conversion and storage, fuel cells, nonlinear control and optimization.*

3 Thesis subject

The modern energy sector is converting rapidly towards natural renewable sources, to cut down on the dependence on fossil fuels. In order to profit from these sources, such as solar, wind, biomass and hydropower, their intermittent energy production needs to be utilized efficiently. Energy storage is an essential requirement for the integration of these renewable sources into the smart grid.

Electric vehicles are expected to have a significant influence in future energy systems. Battery powered vehicles can be charged during lighter load hours, whereas their stored energy can be re-injected into the grid when they are connected to the grid, for peak shaving and valley filling. Fuel cell powered vehicle can be connected to the grid in the same way when they are not in use, in order to balance short term demand/production differences. In return, electricity can also be stored in form of hydrogen through electrolysis of water. However, since these vehicles are not dedicated storage resources, necessary planning, monitoring, control and optimization measures need to be taken for predicting the amount of energy and storage capacity in the grid at a given moment and using them efficiently.

This doctoral proposition is based on problems related to such a system, based on a fleet of fuel cell electric vehicles. The candidate will work in liaison with ALPStore, a multi-national European project on energy storage. The aspects to be studied include the technical, economical and logistic feasibility of power to gas conversion (hydrogen and methane). Electrolysis involves strong interaction between different electrical, electrochemical and thermal processes. The main research work will focus on the modeling and nonlinear control of electrolysis for hydrogen production on the storage side. On the recuperation side, fuel cell dynamics and problems related to the integration of fuel cell vehicles with the grid will be addressed. Dynamic physical modeling and control of the energy conversion chain and optimized storage resource management methods are the perceived results. The requirements for an effective ICT infrastructure for global system control are also to be defined during the research work. In the context of the project ALPStore, these results will aid policy makers in planning future energy networks and integrating storage solutions.

4 Related Publications

I. Matraji, F. S. Ahmed, S. Laghrouche, M. Wack. *Comparison of robust and adaptive second order sliding mode control in PEMFC air-feed systems*. International Journal of Hydrogen Energy, Volume 40, No 30, pp. 9491-9504, 2015.

S. Laghrouche, J. X. Liu, F. S. Ahmed, M. Harmouche, M. Wack. *Adaptive Second Order Sliding Mode Observer Based Fault Reconstruction for PEM Fuel Cell Air-Feed System.* IEEE Transactions on Control Systems Technology, Volume 23, No 3, pp. 1098-1109, 2015.

S. Laghrouche, M. Harmouche, F. S. Ahmed, Y. Chitour. *Control of PEMFC Air-Feed System using Lyapunov-based Robust and Adaptive Higher Order Sliding Mode Control.* IEEE Transactions on Control System Technology, Volume 23, No 4, pp. 1594 -1601, 2015.

J. X. Liu, S. Laghrouche, F. S. Ahmed, M. Wack. *PEM Fuel Cell Air-Feed System Observer Design for Automotive Applications : an Adaptive Numerical Dierentiation Approach*. International Journal of Hydrogen Energy, Volume 39, No 30, pp.17210-17221, 2014.

J. X. Liu, S. Laghrouche, M. Wack. *Adaptive-Gain Second Order Sliding Mode Observer Design for Switching Power Converters.* Control Engineering Practice.Volume. 30, pp. 124-131, 2014.

5 Background

The applicant is expected to have a solid background in electrical engineering and energy conversion. Adequate knowledge of nonlinear control systems and diagnosis is also required.