Modular DC-DC power converter for single fuel cell-based hybrid power supply for heavy duty transportation systems

The Heavy Duty Vehicles (HDV) used in the transport of goods and people, both on road and in the maritime domains, are among the most polluting transport systems where it is becoming urgent to find solutions to reduce their carbon footprint. The electric motor is presented by public and private specialists as the best solution capable of replacing conventional internal combustion engines regarding the environment criteria such as the pollution problems and the energy independence issue. This research project focuses on the use of the Fuel Cell (FC), as a main source of energy combined to an Energy Storage System (ESS) to ensure the reversible power on board of HDVs. The ESS aims to supply the motors when they either are overloaded or subject to load fluctuations and to recover the kinetic energy from electric axles during braking phases. The use of one or several FCs combined with one or several ESSs for supplying high power and high voltage electrical loads (traction motor and onboard grid) having typically a power range higher than 150 kW and DC bus voltage value between 800V and 1500V, requires the combination of several power converters to ensure reliable, efficient, smart power supply and energy management on board of the vehicle. Indeed, even the FCs technology is mature and has been successfully used by several manufacturers in the last years in both marine and road vehicles, its efficiency, its sensitivity to impurities in the hydrogen, its complex internal water management, and its moderate lifetime still need to be improved or at least correctly managed. Thus, multi-FCs multi-ESSs hybrid power supply systems require the use and the assembly of multiple DC-DC converters as shown in the example of figure 1.

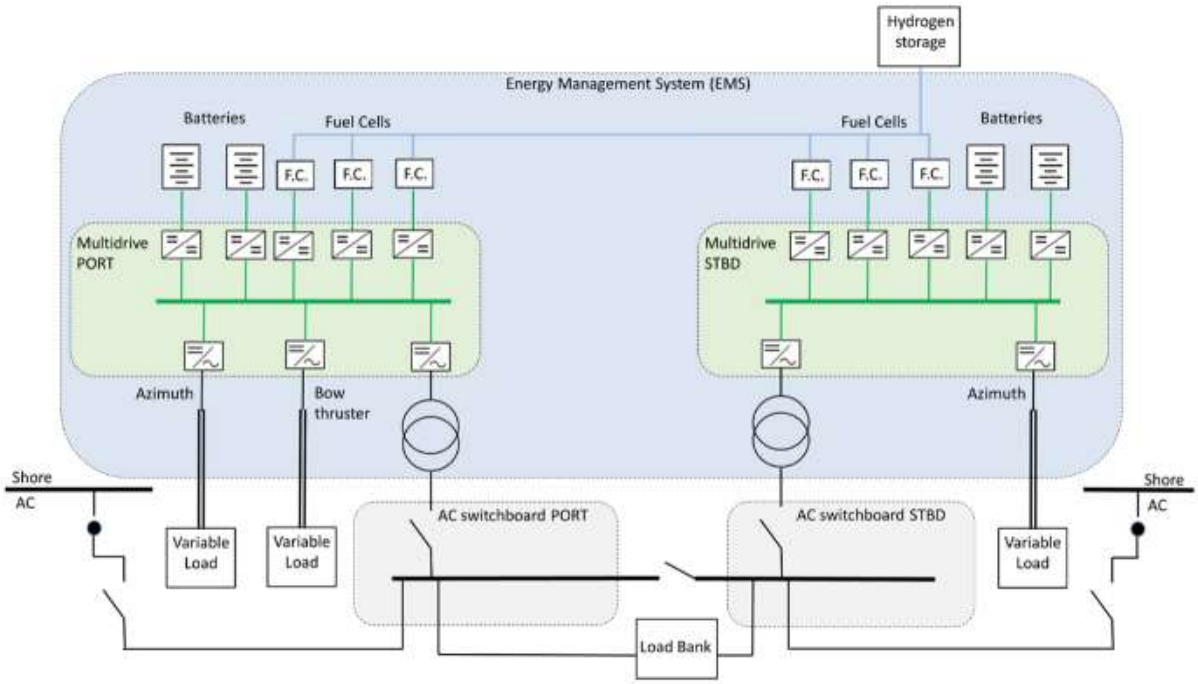

Figure 1 – Example of Hybrid FC and battery power supply in a marine application [Deliverable 1 – HySysPEM project]

In the framework of the PEPR HySysPEM project, the objective of this PhD thesis is to develop a modular, high efficiency and high-density DC-DC power converter topology including the real-time control of the electric power flow in the framework of multiple existing fuel cells and ESS.

The control has to be developed according to the hydrogen storage level, the ESS available SOC, the durability of the FC system, the performances, efficiency and safety of the power transfer. The hybridization will also prevent the FC system from the load power transients (pics of power). Different types of hybridization will be considered, including especially direct hybridization with supercapacitances, leading to an increase of power density of the whole power conversion architecture. Moreover, the assembly of several of this modular power converters will allow easy and optimal connecting the multi-FC and multi-ESS system on the one hand to a medium voltage DC bus (800V – 1500V) and on the other hand to hydrogen and oxygen supply devices as well as temperature and humidity management systems.

Description of work

- Bibliography study on single FC – single ESS DC-DC power converters.
- Comparative study of at least two topologies of single FC – single ESS DC-DC power converters and choosing the optimal solution regarding modularity, efficiency, reliability, cost, ...
- Modelling and numerical simulation of the proposed topology for its design and control.
- Development of automatic control of the proposed architecture, its implementation and validation through numerical simulation.
- Development of energy management strategy and its validation through numerical simulation.
- Demonstration of the modularity ability of the proposed topology through numerical simulation.
- Development of experimental test bench (full or mid-size of HIL) and to validate the proposed power converter topology and the theoretical concepts (design, efficiency, current-voltage-power waveforms, modularity).
- Publication of at least 3 scientific papers including at least one international journal and one international conference.
- PhD thesis report and defence.

Salary

- 2135€ brut per month

Applicant profile

The candidate should have solid knowledge in electrical engineering (energy conversion, power electronics), power system control, numerical simulation and experimentation.

Applications

Applications have to be made through the CNRS website, in “Centre Est” geographic zone:

- https://emploi.cnrs.fr/

Involved research labs

- FEMTO-ST Institute, CNRS, SHARPAC research team, Belfort, France
- LEMTA, CNRS, Nancy, France

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