TRAINING MODULES – FC CONTROL SYSTEM

INNOVATIVE COST IMPROVEMENTS
FOR BALANCE OF PLANT COMPONENTS
OF AUTOMOTIVE PEMFC SYSTEMS

INN·BALANCE
AUTOMOTIVE FUEL CELL

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1. PARTNERS ROLE

AVL List GmbH

- Development of the simulation model of the anode module
- Development of the THDA (diagnosis system) algorithm and hardware including measurement equipment
- Design of the control hardware platform and software

Universitat Politècnica de Catalunya

- Stack model calibration and development of control strategies
- Development of an integrated fuel cell operation model, which also incorporates fuel cell degradation parameters

PowerCell Sweden AB, BROSE Fahrzeugteile GmbH & Co. KG, Fundacion Ayesa, PowerCell Sweden AB, Celeroton AG and DLR e.V.

- Development of the simulation model of the cathode module and thermal module, respectively by Brose and DLR
- Specific work on state observers and sensor design by FAY
- PowerCell provided information regarding the operation strategy of the FC stack
- Celeroton provided information regarding static and dynamic performance of the compressor

2. MAIN FUNCTIONS OF THE FC CONTROL SYSTEM

Prime function

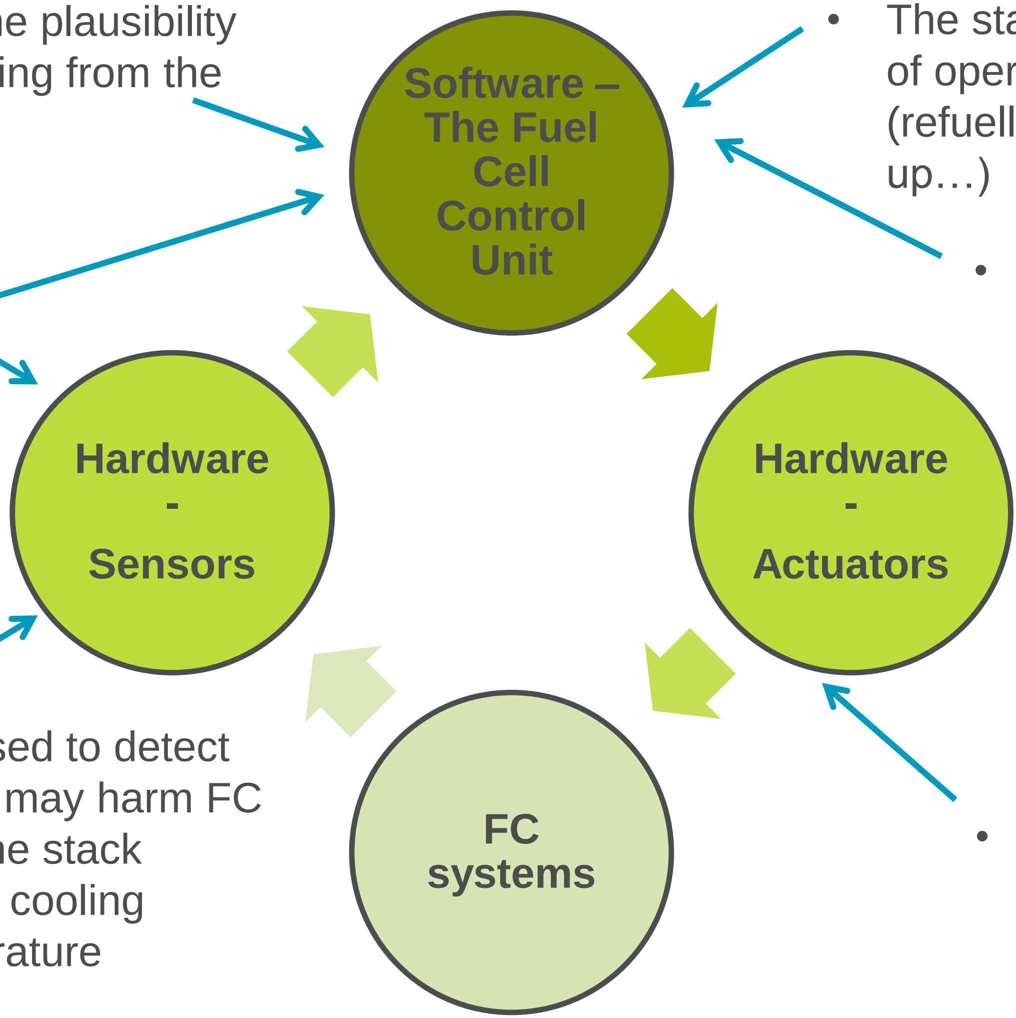
- Ensure smooth running of the fuel cell system and prevent and eliminate as soon as possible any source of disturbance that hamper the functioning of the system. Since a fuel cell does not have any moving part, the only way to adjust the operating conditions is to regulate the parameters of the media going into the FC stack (mass flow, humidity, temperature and pressure…)

Secondary functions

- Ensure the best efficiency and performance of the fuel cell system in every operating modes
- Condition monitoring: precise monitoring of fuel cell parameters to identify significant changes that are indicative of a developing fault. Thus, actions to prevent damages can be taken and the lifetime of components can be significantly extended
- The FC control unit is the brain of the FC system and as such directly communicates with the vehicle control system that interconnects all other equipment and sensors in the vehicle

3. FC CONTROL SYSTEM COMPONENTS

- Observers: will check the plausibility of all input signals coming from the sensors
- THDA diagnosis system based on total harmonic distortion analysis that gives information of the operation conditions within the stack
- Some sensors will be used to detect critical conditions which may harm FC components including the stack pressure and stack inlet cooling temperature and temperature difference



- The state machine decides the mode of operation of the fuel cell system (refuelling, service, normal start-up…)
- Supervisory controller: its objective is to maximise efficiency and avoid degradation of the fuel cell stack. It will provide reference values to the subsystems (anode & cathode module and thermal management system)
- Motors that adjust the position of the valves, coolant pumps

4. AN INNOVATIVE DIAGNOSIS SYSTEM: THE THDA

Advantages

- Total Harmonic Distortion Analysis (THDA) is a method of applying a specific current to the stack and analysing the response signal that provides information on the operating conditions within the stack. This method is non-intrusive and can easily be implemented in any fuel cell system.
- Compared to conventional solutions such as cell voltage monitoring which requires complex instrumentation, the THDA diagnosis method is more reliable and allows to improve packaging of the fuel cell system.
- Another advantage of THDA is to be able to predict the cause of declining cell voltages. Thus, it allows to avoid harmful conditions such as droplet formation, dry out of the membrane that may otherwise lead to irreversible damages

→ Please visit our YouTube channel and watch and listen to Jan Schmidt, engineer at AVL, explaining the principles of the THDA technology for fuel cell monitoring in automotive applications: https://www.youtube.com/watch?v=CakSjTZEfQQ

5. SPECIFIC CHALLENGES RELATED TO THE DEVELOPMENT PROCESS

Development of an integrated fuel cell operation model

- Due to the complexity of the FC control system, the integration of all subsystem models into the integrated model took more time than initially planned. Indeed, each modification of the subsystems models impact the architecture of the general model.

Development of a fuel cell degradation model

- The fuel cell degradation model which is part of the FC control model aims at minimizing the degradation of fuel cell. The model - which is complex - estimates the electrochemical surface area during running operation based on the radius and quantity of the particles as well as the amount of water in the FC stack.

→ Please visit our YouTube channel and watch and listen to Dr. Attila Husar, researcher at the fuel cell laboratory of the Polytechnic University of Catalonia, revealing more of his work in INN-BALANCE on modelling degradation of fuel cells in automotive applications: https://www.youtube.com/watch?v=r-E-c2q-HyE

Compactness and compatibility with FC system

- The control system hardware and THDA hardware must be of reduced volume to allow for a better integration in the fuel cell system and vehicle powertrain.

6. MAIN DEVELOPMENT STEPS

Steps taken during the development of the control system

1. Development and validation of the fuel cell stack model by UPC using data provided by PowerCell
2. Development of the integrated model consisting of subsystems of the fuel cell system. This model is used to simulate and control the FC system in all possible modes. Partners UPC coordinated this tasks with inputs from AVL, DLR, BROSE
3. Development of control strategies based on requirements and operating strategies provided by the partners. UPC led this task with inputs from all industrial partners
4. Development of the THDA (diagnosis system) algorithm and hardware including measurement equipment by AVL
5. Selection of a control unit according to the FC system requirements and development of the control software architecture to integrate all software components by AVL
6. Validation of the control system in laboratory environment by PowerCell and in final vehicle tests by CEVT