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INNovative Cost Improvements for BALANCE of Plant Components of Automotive PEMFC Systems

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Deliverable 4.4
Public results of Anode module

Authors: Dr. Alexander Schenk
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RE	Restricted to a group specified by the consortium (including the FCH2 JU Services)	
CO	Confidential, only for members of the consortium (including the FCH2 JU Services)	

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CHANGE CONTROL

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Table of content

1. Introduction

1.1 Anode module design concepts

The aim of INN-BALANCE is to develop a novel and integrated development platform for developing advanced Balance of Plant components in current fuel cell based vehicles, to improve their efficiency and reliability, reducing costs and presenting a stable supply chain to the European car manufacturers and system integrators. In this context, a hydrogen supply and recirculation system (i.e. anode module) for a passenger car was developed, tested, and integrated.

1.2 Scope of work

This document summarizes the concept and the design of the anode module and shows gained testing results from testbed operation.

2. Vehicle requirements

This chapter lists the vehicle requirements.

2.1 Environmental conditions

- Standard Ambient conditions:
  - Atmospheric pressure: 983 hPa (300 m above sea level)
  - Temperature: 298 K
- Temperature range
  - The vehicle must be able to start from -30 °C
  - Drivable from -40 °C to 52 °C
  - Increasing drivability problems are allowed from -40, although not stalling

2.2 Hydrogen supply

- Anode flow:
  - Min-Max: 140-2005 slpm
  - Nominal: 1689 slpm
- Anode temperature:
  - Nominal: 73°C
  - Max: 90 °C
- Anode pressure:
  - Min-Max: 150-2350 mbar(g)
  - Nominal: 1350 mbar(g)
- Hydrogen quality:
  - ISO 14687-2 or SAE J2719. Traces from oils or ionic liquids from filling station gas compression not acceptable.

3. Anode module functionality

Hydrogen is stored in fuel cell vehicles in one or more pressure tanks at 70 MPa. The supply pressure for the hydrogen injection system is in the range of 10-20 bar(a). The hydrogen injection valve supplies the fuel cell stack and ensures a certain fuel stoichiometry by passive recirculation.

4. Anode module design

To support the design of the anode module 3D-CFD simulation with AVL Fire v2014.2 was used. The fuel cell stack defined the boundary conditions for the 3D-CFD simulation.

Steady-state simulation was performed for a volumetric gas composition of H_2/N_2 (70/30). Detailed simulation reports are available at AVL.

4.1 Layout of the anode module

The final anode layout is shown in Figure 1.

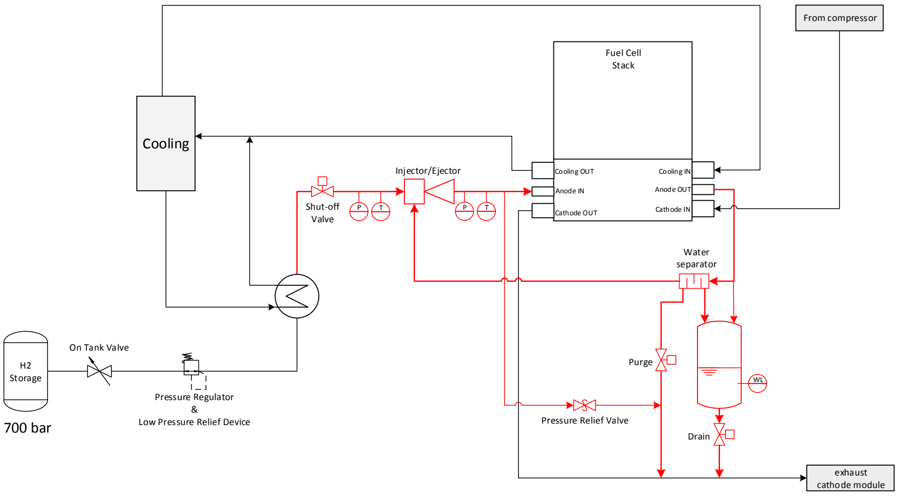


Figure 1: Detailed depiction of the anode module

The anode module design consists of the following components:

- Anode heat exchanger
- Temperature- and pressure sensor upstream of the injection valve
- Shut-off valve
- Injector/ejector unit
- Pressure relief device
- Temperature- and pressure sensor upstream anode inlet
- Water separator
- Water level sensor
- Drain- and purge valves
- Purge/bleed valve (V-3)

4.2 Designing the anode module

The above-mentioned components were fully integrated into the media supply unit (MSU).

Figure 2 shows the final design of the anode module.

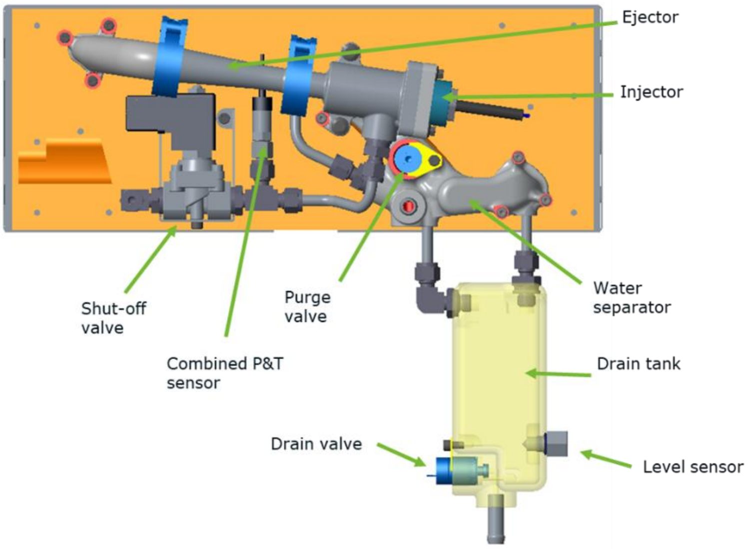


Figure 2: Final anode module for vehicle demonstrator

5. Summary anode module design

This deliverable presents the anode module design and its components for supplying the PowerCell S3-335 fuel cell stack with hydrogen. A highly integrated solution, which allows to fulfil all requirements for operating the fuel cell stack safely in a demonstration vehicle was developed by AVL, and comprises the following functions:

- pre-heating of hydrogen to stack inlet temperature
- temperature and pressure sensors for monitoring and control
- supply of hydrogen with passive recirculation system
- pressure relief in case of malfunction

6. Injector/Ejector testing results

In parallel to the CFD simulation tests were performed to validate the design. Figure 1

The average suction pressure measured was 340 mbar. Figure 3 shows exemplarily the time-based pressure curve of ejector inlet (blue) and outlet (red).

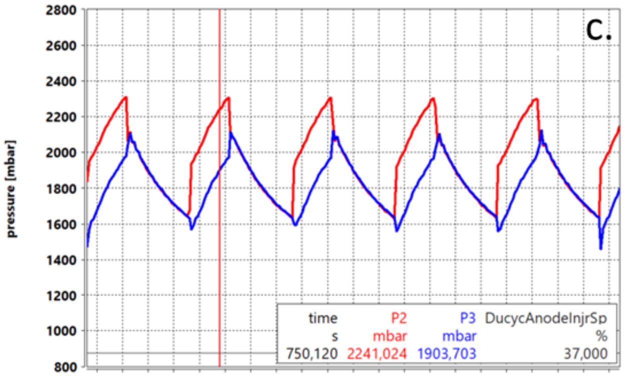


Figure 3: Time-based pressure curve of ejector inlet (blue) and ejector outlet pressure (red)

Based on this measurement, the minimal hydrogen concentration at stack outlet of 56 vol% has been defined to ensure sufficient fuel stoichiometry.

7. Fuel cell system tests

This chapter shows the basic anode related measurements of fuel cell system operation at the testbed. The measurements have been recorded in an early commissioning state don’t represent the optimized system operation strategy.

7.1 Stationary operation and load change

Figure 4 shows the cathode pressure (blue), the anode pressure (light grey) as well as a filtered signal of the anode pressure (red). Further, the anode pressure deviation (set vs. act.) is shown (light grey and filtered in brown). In addition, the cathode mass flow (green), the stack current (dark blue), the stack voltage (purple) and the coolant temperature (turquois) is plotted. Since the anode pressure deviation does not exceed the limits according to the requirements, the acceptance criteria for anode pressure control have been met.

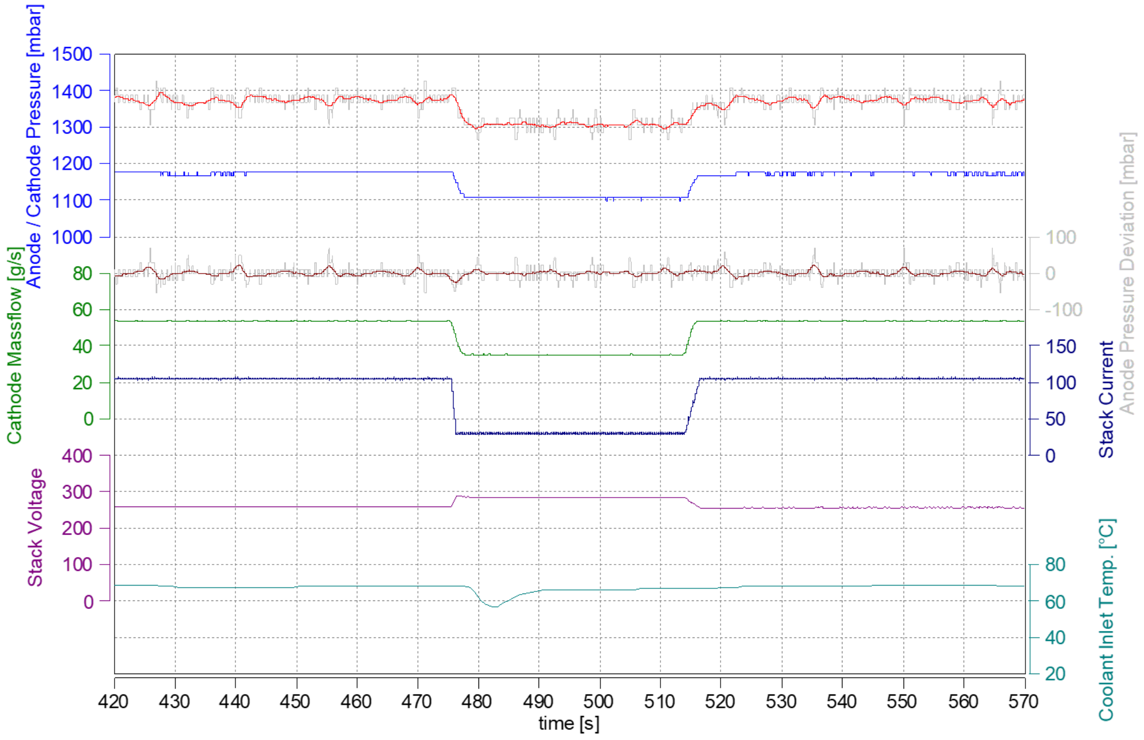


Figure 4: Time-based diagram of stationary operation and load change

7.2 Start up

Figure 5 shows the signals described in 7.1 during the start-up of the fuel cell system. The transient set point change for the anode pressure was met without exceeding the limits for the pressure deviation. Therefore, the acceptance criteria for the anode pressure control during start-up have been met.

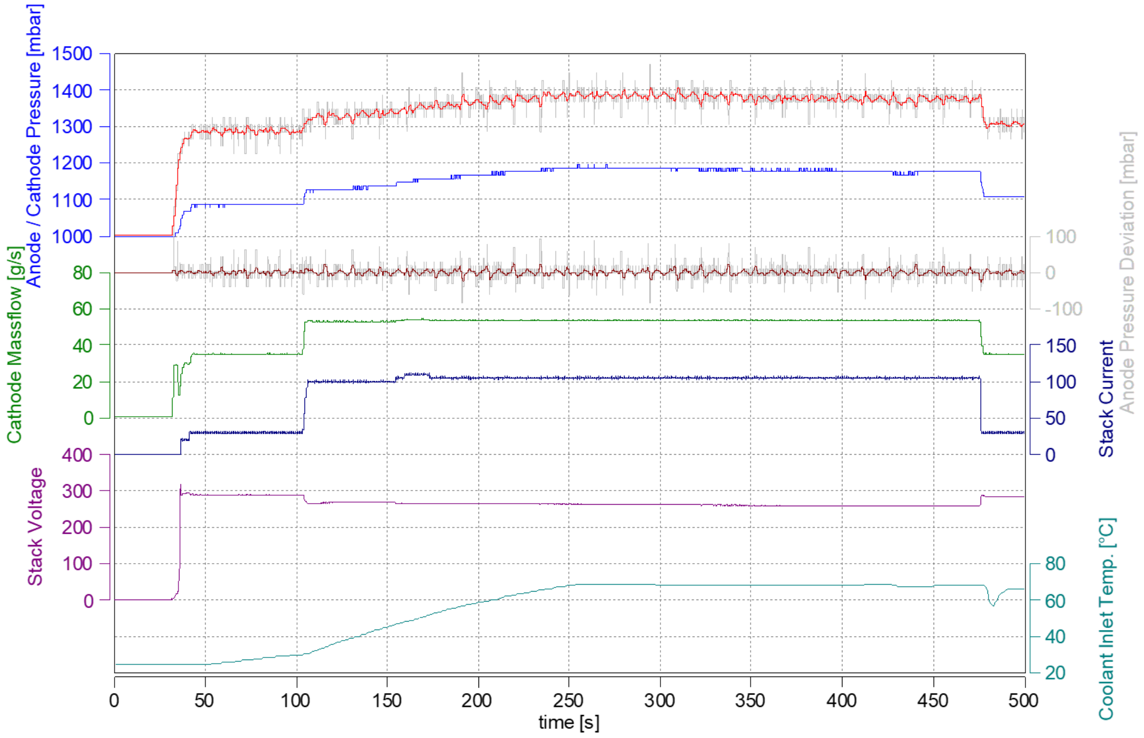


Figure 5: Time-based diagram of system start up

7.3 Shutdown

Figure 6 shows the signals described in 7.1 during the shutdown of the fuel cell system. The transient set point change for the anode pressure was met without exceeding the limits for the pressure deviation. Therefore, the acceptance criteria for the anode pressure control during shutdown have been met.

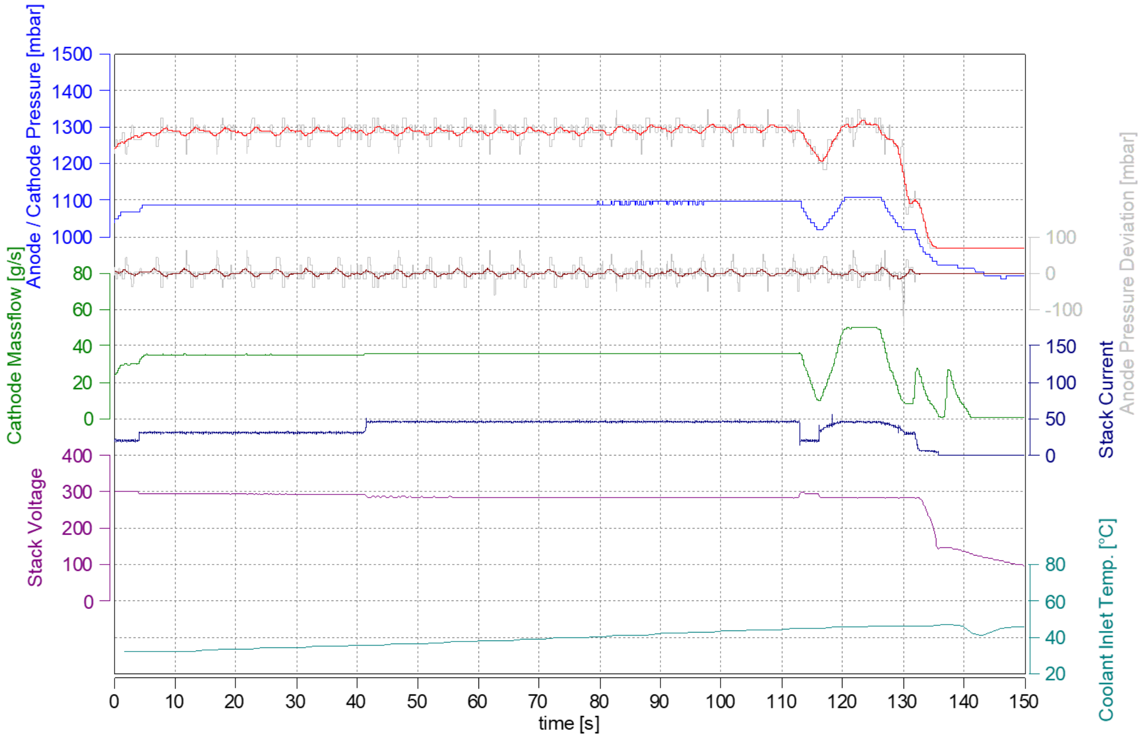
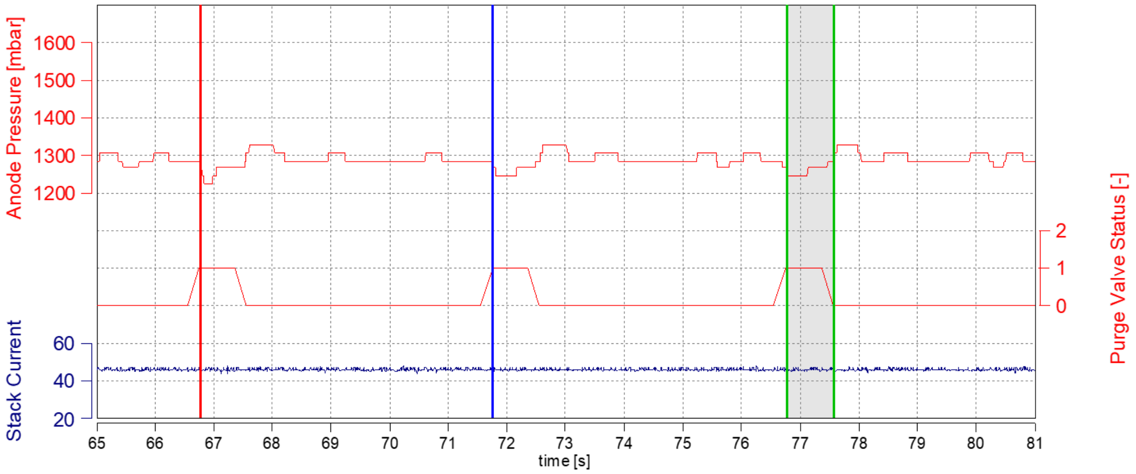


Figure 6: Time-based diagram of system shut down

7.4 Purge Strategy

Figure 7 shows the binary purge signal (red) as well as the anode pressure (red) during the purge events at low load condition. In this case, the period between purge events has been calibrated to 5 s whereas the opening duration has been calibrated to 0.8 s. These values need to be optimized during further tests.

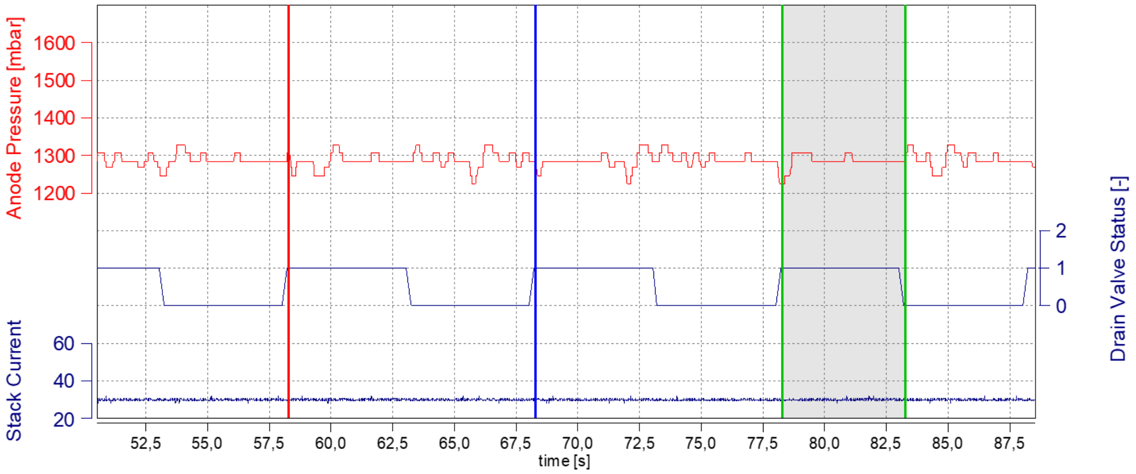


N°	time	Anode Pressure	Stack Current	Purge Valve Status
	s	mbar		-
1	66,770	1286,190	45,000	1,000
2	71,770	1265,873	46,025	1,000
DIFF(2-1)	5,000	-20,318	1,025	0,000
3	76,780	1265,873	46,000	1,000
4	77,580	1286,190	45,057	0,000
DIFF(4-3)	0,800	20,318	-0,943	-1,000

Figure 7: Time-based diagram of the purge strategy in low load condition

7.5 Drain Strategy

Figure 8 shows the binary drain signal (dark blue) as well as the anode pressure (red) during the purge events at low load condition. In this case, the period between drain events has been calibrated to 10 s whereas the opening duration has been calibrated to 5 s. These values need to be optimized during further tests.



N°	time	Anode Pressure	Stack Current	Drain Valve Status
	s	mbar		-
1	58,240	1306,508	30,000	1,000
2	68,240	1286,190	30,000	1,000
DIFF(2-1)	10,000	-20,317	0,000	0,000
3	78,250	1225,238	29,000	1,000
4	83,250	1286,190	30,000	0,000
DIFF(4-3)	5,000	60,952	1,000	-1,000

Figure 8: Time-based diagram of the drain strategy in low load condition