INN·BALANCE
AUTOMOTIVE FUEL CELL

INTERVIEW WITH JAN SCHMIDT, INN-BALANCE PROJECT MANAGER AT AVL RECORDING THE 'VIBES' (HARMONICS) OF A FUEL CELL SYSTEM – INN-BALANCE FUEL CELL CONTROL UNIT

To ensure smooth running of the fuel cells in a car, any source of disturbance that hampers their functioning has to be eliminated as soon as possible. Control and diagnosis devices are therefore an important component of every fuel cell system. In INN-BALANCE the goal of AVL's work has been to develop an on-board diagnosis system for fuel cells.

Jan Schmidt from AVL agreed to answer a few questions about the diagnosis strategy pursued in INN-BALANCE and the device, which is currently being evaluated on the fuel cell test benches of PowerCell.

Portrait - Jan Schmidt, AVL

Since having joined the project in October 2018, Jan Schmidt has worked on the first ever on-board diagnosis system for electric vehicles powered by fuel cells. In this interview he looks back on the results achieved and casts light on the next steps.

Jan Schmidt is a Development Engineer for PEM Systems at AVL for two years. Before, he studied process engineering at the Technical University of Vienna, gaining first job experiences at equipment manufacturer Andritz and international carmaker Daimler AG.

For an introduction to the subject, could you please explain potential defects that can occur in a fuel cell system and its impact on performance/reliability? What are the main risks and how to mitigate them?

Since a fuel cell does not have any moving parts, the only way to adjust the operating conditions is to regulate the parameters of the media going into the stack. The chemical reaction within the fuel cell is affected by these parameters. By operating at low temperatures for example, water droplets can form. If the droplet is on the catalyst layer surface, the active area gets blocked and local fuel starvation can occur. This phenomenon is likely to take place during cold starts when the temperature of the stack is low, or when the cooling flow is not controlled properly. A possible way to mitigate this risk is to ensure a higher pressure, or higher stoichiometry in the anode.

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The opposite happens when the temperature of the fuel cell is too high, or the humidity of the air inlet flow is too low. These not ideal operation conditions cause the Membrane Electrode Assemblies (MEA) to dry out. This in turn causes a higher degradation of the membrane and if not detected quickly, can even result in local hotspots and a complete failure of the MEA. Online monitoring of the stack would make it possible to track the conditions and react immediately if a harming stack environment starts to form.

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What are the advantages of the THDA control method used in INN-BALANCE compared to conventional (more intrusive) methods of fuel cell control and monitoring?

During system operation fuel cells are basically black boxes. We can measure the operating parameters before and after the stack but what is happening inside is hard to tell. Therefore, online monitoring of the conditions within the fuel cell is extremely important. By getting this insight into the stack during operation we can optimize our operating strategy and therefore increase the lifetime of today's fuel cell systems.

The Cell Voltage Monitoring (CVM) is the state-of-the-art method that we are using today and it is used in the majority of applications. This solution is not just costly because of its complex instrumentation, but also unreliable since every, or at least most cells have to get wired separately. Since stacks can have more than 330 Cells, the likelihood of at least one of them failing is high.

Total harmonic distortion analysis or THDA is a method where a specific current signal is applied to the stack. The analysis of the response signal gives information of the operation conditions within the stack. This way online monitoring becomes possible and we can immediately react with changes to the operating conditions to prevent damages to the stack. In addition, this method can be implemented into existing fuel cell system components like the DC-DC converter and the Fuel Cell Control Unit (FCCU) which allows us to improve packaging by removing the CVM and ensure a more robust operation.

„With THDA we can predict the cause of declining cell voltages and therefore avoid harmful operating conditions of the fuel cell"

In a nutshell, with CVM we can detect declining cell voltages but with THDA we can predict the cause of declining cell voltages and therefore avoid harmful operating conditions (e.g. droplet formation, low media, dry out of the MEA).

As a next step the functioning of the on-board diagnosis and control system, its reliable report of disturbances and damages within the fuel cell system and its automatic control of BoP components, will be tested on the test benches of PowerCell in Sweden. Could you please outline the setup and scenarios of these tests?

In this case we will be using our AVL THDATM test device, which is normally used on test stands, the same product that AVL already has available for customers. The THDA will act as a tool for system design verification and optimization of the operating strategy. By monitoring the humidification, the THDA detects membrane dry out and flooding. With this additional monitoring opportunity, DLR (Deutsches Zentrum für Luft- und Raumfahrt) for example, will be able to predict the duration until the system is ready for shut-off and therefore optimise the duration of the overall freeze shut down procedure.

The AVL THDATM test device © AVL 2019

Another scenario we are taking into account, is hydrogen starvation, which is really common during freeze starts. Here the starvation is tracing back to droplet formation what could be avoided by adjusting the stoichiometry of the fuel supply.

To cut it short, online monitoring of the membrane humidity is giving us the possibility to adjust operation conditions in realtime and helping to prevent harmful operating conditions.

Thank you Jan, for providing an interesting insight into the work of AVL!