Project Deliverable

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325275	SAPPHIRE	System Automation of PEMFCs with Prognostics and Health management for Improved Reliability and Economy
Instrument:		**Thematic Priority**
Collaborative Project (CP)		FUEL CELL AND HYDROGEN JOINT UNDERTAKING
Title:		
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Dissemination level (Project co-funded by the European Commission within the Seventh Framework Programme)		
PU	Public	**PU**
PP	Restricted to other programme participants (including the Commission)	
RE	Restricted to a group defined by the consortium (including the Commission)	
CO	Confidential, only for members of the consortium (including the Commission)	Public

MCP – Hannover Fair

Authors (organizations):

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Abstract :

The SAPPHIRE results were presented at the Hannover Fair in April 2016, which is one of the most famous industrial fair in Europe. The SAPPHIRE booth was located in the group exhibit “Fuel Cell and Battery Exhibition”, the Europe's largest exhibition in the hydrogen field. More than 30 contacts were established with visitors coming from 16 different countries. A presentation of the results has been done by the coordinator in the technical forum, the video is available on the fair website as well as on Youtube.

Keywords :

Hannover Fair, Fuel cell and Battery Exhibition, technical forum

Revision History

Rev.	Date	Description	Author (Organisation)
1.0	June 8, 2016	First draft	Péra (FCLAB)
1.1	June 8, 2016	Minor corrections, layout, higher-resolution pictures in annex	Zenith (SINTEF)
1.2	June 8, 2016	Change fuel from methane to natural gas in chapter 2	Pedersen (Dantherm Power)

Table of Contents

1 Introduction

Initially, two workshops were scheduled at Month 11 and Month 36. The first one was postponed to take place in link with an IEEE international conference and was held the 26th of October 2014, in Coimbra, Portugal. At the mid-term review, the consortium proposed to the evaluators and the officer to replace the M36 regular workshop by a presentation of the SAPPHIRE results at the Hannover Fair (http://www.hannovermesse.de), in the "Fuel Cell and Battery" Group Exhibit (http://www.h2fc-fair.com), as a worldwide event that gathers main actors of industrial R&D and marketing in hydrogen.

2 Presentation of SAPPHIRE results at the Hannover Fair

The SAPPHIRE results were then presented at the Hannover Fair during five days, 18-22 April 2016.

The SAPPHIRE corner booth was located not far away from the public forum, in a busy and visible part of the fair (Figure 1).

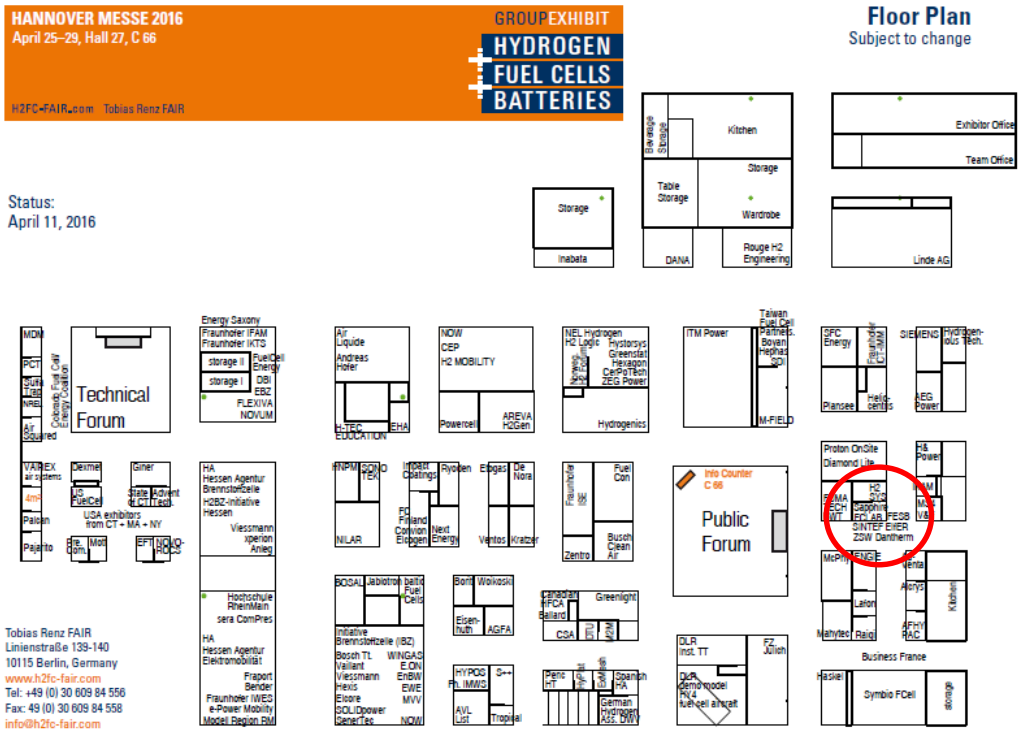


Figure 1: Floor plan of the Fuel Cell and Battery Exhibition

The material shown on the booth was:

- The Dantherm Power cabinet of the natural gas-fed fuel-cell system for combined heat and power;
- The stacks and fuel cell components of ZSW;
- Posters presenting the main contribution and results of FCLAB, ZSW, SINTEF, Dantherm Power
- Brochures to be distributed to the visitors (see the annex).

The project has been advertised in the fair website, as depicted in Figure 2 (http://www.h2fc-fair.com/hm16/exhibitors/sapphire.html).

Figure 2: Exhibitors Highlight 2016

More than 30 contacts were established with visitors coming from 16 different countries. The complete list of contacts has been circulated among partners.

Figure 3: Visitors at the SAPPHIRE booth

Figure 4: Sapphire partners at the booth

We had also a VIP visitor: the French Minister of Economy, Emmanuel Macron spent about 10 minutes at the booth, asking questions about competitive advantages of hydrogen (Figure 5).

Figure 5: Visit of Emmanuel Macron, French Minister of Economy

The coordinator presented the project results in the technical forum, advertised on the website of the fair (Figure 6).

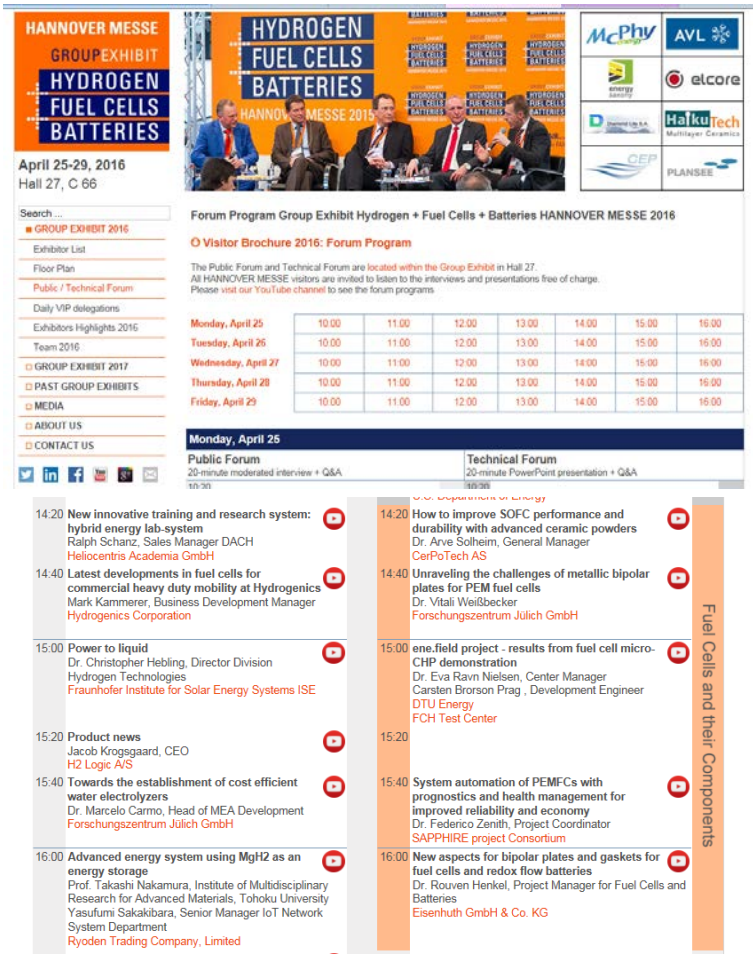


Figure 6: Announcement of the presentation of SAPPHIRE at the Technical Forum

The video of the presentation is available on the fair website as well as on Youtube (Figure 7). (https://www.youtube.com/watch?v=8gBm8qxQEmc).

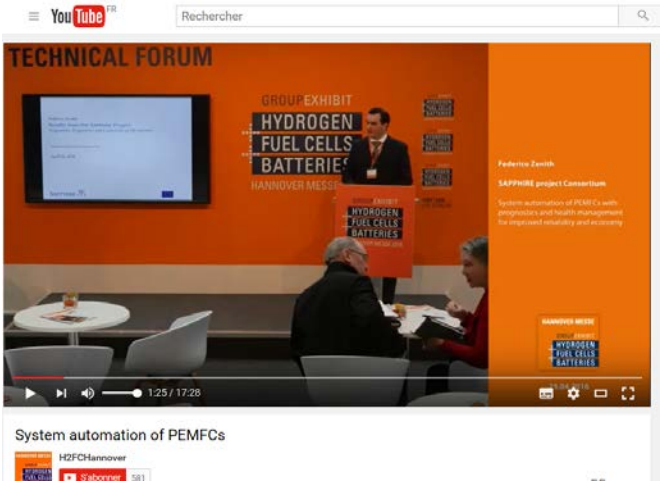


Figure 7: Technical Forum available on line

3 Conclusion

The results of SAPPHIRE were presented at the Hannover Fair. The booth encountered a nice success with interesting discussions and contacts with visitors. The highlights of the project were presented at the technical forum by the coordinator.

4 Annex: flyers

SAPPHIRE

System Automation of PEMFCs with Prognostics and Health management for Improved Reliability and Economy

Dantherm Power a partner within the Sapphire project

Dantherm® Power
A Ballard Backup Power Company

Dantherm Power is a joint venture between Ballard Power Systems Inc. and Dantherm A/S. DTP is an international enabler and the leader in Europe when it comes to the commercial application of hydrogen and fuel cell technologies. We are involved in both Danish and international research initiatives within hydrogen and fuel cell technologies and we are ready to introduce a reliable solution whenever hydrogen and fuel cells prove to be a commercially and environmentally viable alternative to traditional energy supply applications.

Dantherm Power is currently testing the Sapphire controller on the natural gas powered micro-CHP fuel cell system. The Systems are developed and manufactured by Dantherm Power. Dantherm Power is supporting the Sapphire project with:

- Fuel cell systems
- System specifications
- Pre-existing test data
- 2 x 3000 hour reference test including data analysis
- Sapphire controller implementation
- 2 x 3000 hour test with sapphire controller implemented
- Evaluation of the Sapphire controller through data analysis

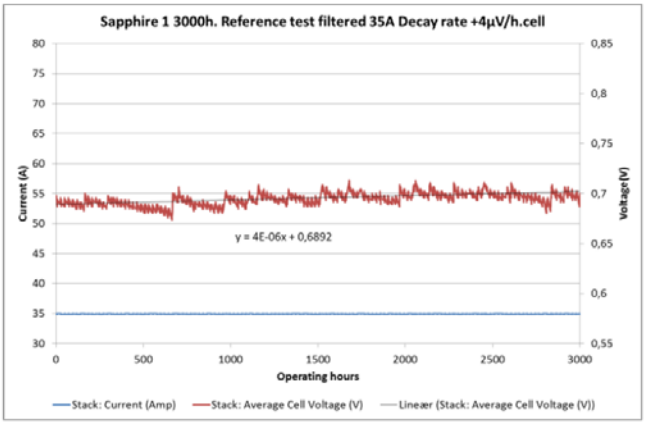
Technical data fuel cell system

- Dimension: 180 x 61 x 61cm (H x W x D)
- Electrical net power: 900 Watt 33,6% electric efficiency
- Thermal power: 1468 Watt 54,9% thermal efficiency
- Fuel cell: LT-PEM 46 cells of 100cm2

Main results

Pre-existing system data shows that the fuel cell degradation is 2 µV/h.Cell. The data generated in the Sapphire project shows the following results:

- 3000 hour reference test on the Sapphire systems with load profile operation :
  Sapphire 1: +4 µV/h.Cell
  Sapphire 2: -0,2 µV/h.Cell
- The positive result in the reference test is governed by many unplanned shutdowns due to communication error between system and extra added hardware. Load changes due to the load profile could also have an impact.
- 3000 hour test with Sapphire controller implemented is being conducted. Data not available until end of project.



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Dantherm® Power
A Ballard Backup Power Company

The research leading to these results has received funding from the European Union's Seventh Framework Programme (FP7/2007-2013) for the Fuel Cells and Hydrogen Joint Technology Initiative under grant agreement n°325275.

Reducing Degradation in PEMFCs with Process Control

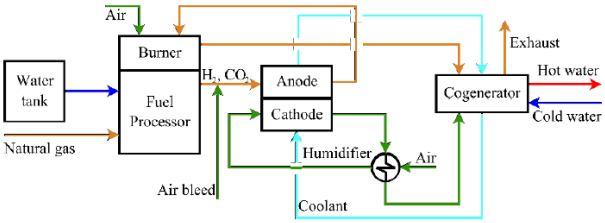
The SINTEF Foundation

SINTEF is the largest independent research institution in Scandinavia. Its 2100 employees from 70 different countries possess leading-edge expertise at international level in science and technology, medicine and the social sciences. SINTEF is a non-profit organisation, and it reinvests its earnings in new research projects, scientific equipment and competence development. SINTEFs turnover in 2013 was around 350 million €.

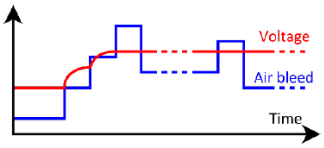
SINTEF Applied Cybernetics is a department focusing on automatic control, robotics and real-time systems; in Sapphire, they develop and validate new control methods to reduce long-term degradation and counteract flooding, drying, CO poisoning and anodic starvation.

SINTEF Applied Cybernetics is also acts as the coordinator of the project.

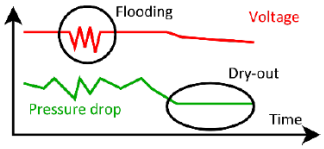
Contribution to the Project

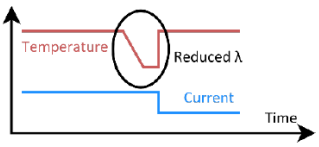


The project started from Dantherm Power's 1 kW µCHP system, which SINTEF analysed for controllability. Dantherm Power did not want costly extra sensors, which ruled out CO sensors or Electrochemical Impedance Spectroscopy. SINTEF proposed a multi-layered approach, with the short-term, regulatory control performed by the current system, mid-term control to actively counteract disruptive processes, and long-term control based on prognostic optimisation of the system's lifetime.



The developed techniques relied almost exclusively on the analysis of data from already available sensors: **CO poisoning** is detected by increasing the air bleed, which causes a measurable voltage surge if CO is present (the opposite transient is much slower); **flooding** conditions are measured by increased noise in voltage instead of the traditional pressure-drop monitoring, which is less reliable in large stacks; **dry-out** is measured by cathodic pressure drop (one extra sensor, priced 68 €, is required), in absolute value or noise, since nominal stack conditions expect droplet formation; **anodic λ** can be estimated by monitoring the flame temperature of anode effluent, which is very sensitive to composition changes.





Most of these conditions can be ameliorated by a temporary modification of operating conditions: adjusting the air bleed for CO poisoning, raising or reducing stack temperature for respectively flooding and dry-out, or rapidly reducing current if anodic λ falls below a threshold.

The control systems have been demonstrated for over 3000 h in two systems. The CO controller significantly reduced air bleeding from the previous worst-case fixed levels. Flooding and dry-out controllers were validated in laboratory tests performed by ZSW. The anodic λ estimator was validated by simulation.

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SAPPHIRE

System Automation of PEMFCs with Prognostics and Health management for Improved Reliability and Economy

Stack experiments performed at Zentrum für Sonnenenergie und Wasserstoff-Forschung BW

ZSW's range of expertise covers the entire battery and fuel cell value chain: from modelling and simulation of electrochemical processes, synthesis and characterization of active materials, to optimization of components, technologies related to high volume production right up to prototype demonstration. Test facilities equipped to the latest standards enable comprehensive testing, assessment and qualification of components and systems in terms of performance, durability and safety. R&D efforts of the fuel cell departments, involved in Sapphire, focus on:

- Modelling, designing and implementing PEM fuel cell stacks and fuel cell systems ranging from 5 W to 100 kW
- Testing components, stacks and subsystems up 120 kWel using application-oriented methods
- Characterization and optimization of fuel cell components
- Conducting degradation and post-mortem analyses
- Investigating automotive system technology

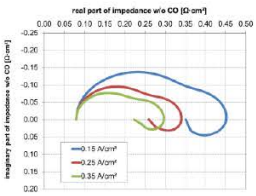
Contribution to the project

ZSW designs and manufactures the fuel cell stacks which are tested at different laboratories within the project. Numerous stack tests, including advanced in situ analysis techniques, have been performed at ZSW serving as inputs for diagnosis and prognosis models of partner institutes. Subject of investigations are:

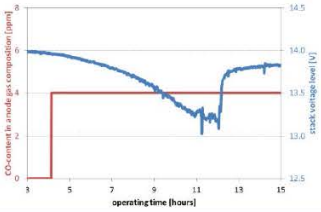
- Poisoning of catalyst layer with carbon monoxide dependent on operating conditions
- Accelerated stress tests
- Performance and endurance tests of stacks equipped with different MEAs

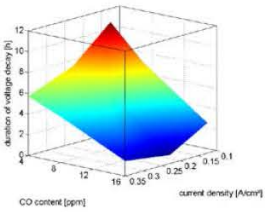
Main results

- Impedance and polarization curves were recorded for varying operating conditions. Both 2000 h endurance tests and accelerated stress test including voltage cycling were performed. The gathered data were used to generate a method defining the actual state of health and predicting future performance.



- CO poisoning and recovery through air bleeding with reference to catalyst composition was investigated and voltage transients calculated. Using these inputs, a controller was developed within the project to optimize the air bleed content.





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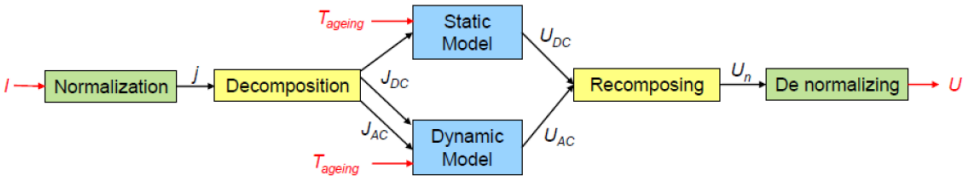
Hybrid-based behavior prediction of a PEM fuel cell

FCLAB

The Federation for Fuel Cell Research CNRS is a joint unit that gathers 120 people (researchers, PhD students, Post-Doc, engineers, technicians and administrative staff) working on fuel cell systems. The applications aimed by FCLAB are systems of energy generation or storage, either embedded (electric and hybrid vehicles, special or consumer vehicles) or stationary (decentralized hybrid supplies, storage plug of electrical energy).

Contribution to the project

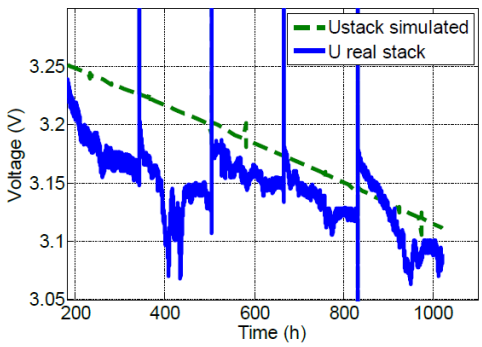
- ✓ Development of prognostic algorithms based on a physic behavioral model.

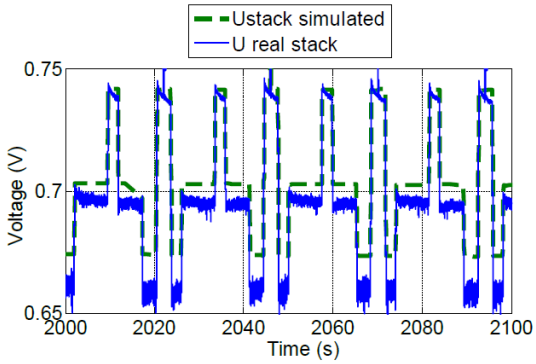


- ✓ Validation of the prediction with several sets of experimental data.
- ✓ Online implementation of the predictive approach.
- ✓ Specification of the need of experimental data (operating points at few current levels and small signal response to a stimulus sent by the output power converter)

Main results

- ✓ Capability and efficiency of the algorithm in predicting the stack's behavior (low computation time, Root Mean Square Error on the voltage prediction less than 0.2 V).
- ✓ Short learning set to obtain an accurate prediction (around 300 hours).
- ✓ Specification of the amount of data needed, in agreement with an online implementation.
- ✓ Genericity of the developed algorithms: success on different experimental tests.





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