INSIGHT

"ImplementatioN in real SOFC Systems of monItoring and diaGnostic tools using signal analysis to increase tHeir lifeTime"

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Research and Innovation Project

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Report on Workshop WS1

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P11 – AK	inputs

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Document Abstract

In the frame of the INSIGHT project, a Workshop has been jointly organised with the Health-code project, coordinated by University of Salerno and having the same approach for PEMFC.

The workshop has been held in Brussels on November 13th, the day before the Program Review Days of the FCH-JU.

The objectives were to give an overview on the current status and the most recent advancements on monitoring, diagnostics and control of both PEMFC and SOFC.

This deliverable gives an overview of the workshop. It describes the purpose, the achievements, the organization and the final outcomes of the event.

Figures about participants are provided in order to point out the interest among the topics presented during the joint workshop.

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1. Introduction

The INSIGHT project aims at developing a Monitoring, Diagnostic and Lifetime Tool (MDLT) for Solid Oxide Fuel Cell (SOFC) stacks.

The workshop presented the most recent advancements concerning research on monitoring, diagnostics and control of both PEMFC and SOFC. It was jointly organized by the HEALTH-CODE and INSIGHT projects. Both projects provide advanced monitoring and diagnostic solutions towards improved performance, better management and maintenance scheduling, aiming at higher reliability and increased lifetime of PEMFC and SOFC technologies.

The workshop gathered engineers and researchers from industry, academia and research institutions interested in the most recent advancements on monitoring and diagnostic tools. Emphasis was given to methodological approaches for advanced diagnosis that can help achieving enhanced performance of both PEMFC and SOFC systems. A comprehensive overview and the exploitation potential of the projects results were offered to the interested stakeholders and users at various levels.

The workshop started with an overview of the projects; then, main results were reported on the experimental activity and on various approaches for monitoring and diagnostics. Scientists and engineers from 15 teams presented their activities, bringing their knowledge, expertise and perspectives. Invited guests from industry offered a further look into key topics tightly connected to monitoring and diagnostics of both PEMFC and SOFC. Exploitation and market opportunities of the projects results were discussed with a representative from the European Commission Support Services for Exploitation of Research Results (SSERR).

A final open discussion among the attendees was set to share experience and draft future paths towards FC improvements via on-board diagnostics.

2. Organization

58 attendants were hosted free of charge. Coffee, beverages and networking cocktails were offered to all participants.

a. Dissemination

The spreading of workshop information among researchers and industries had two main channels: websites and newsletter. The former ones were:

- INSIGHT website: http://www.insight-project.eu
- HEALTH-CODE website: http://pemfc.health-code.eu

As regards the latter media channel, three announcements were sent by email to a chosen mailing list in the period September – November 2018 (see ANNEX 1 for the extract of the newsletter).

b. Logistics

The Workshop was held in Brussels at Manos Conference Centre the day before the Programme Review Days FCH-JU 2018 (see ANNEX 2 for the flyer). The PRD is traditionally held at Charlemagne Building. The conference center is located in the city center (Figure 1) and it is well connected by Metro and bus service.

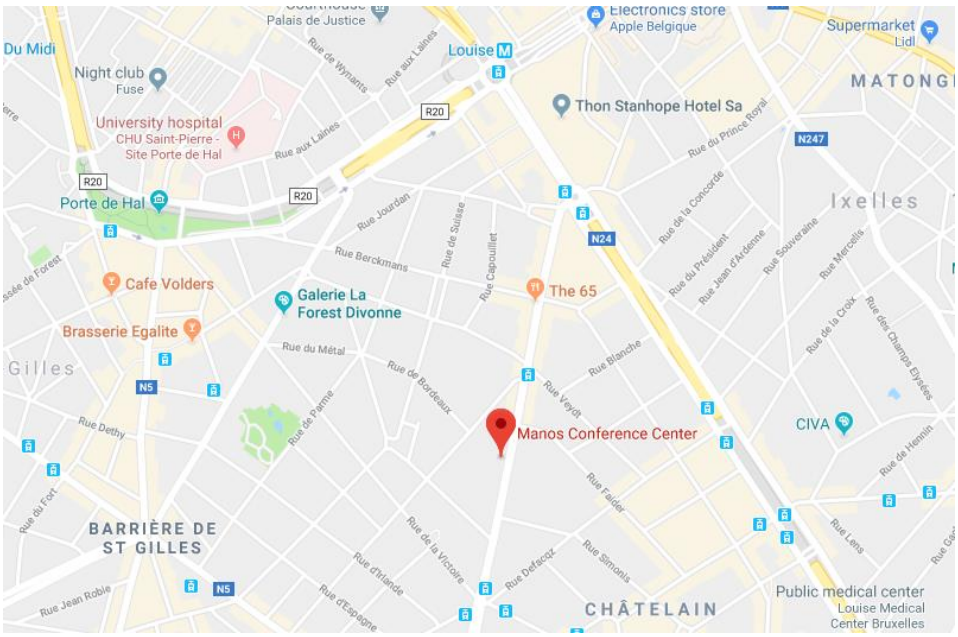

Figure 1 Workshop venue

3. Program

The workshop was divided into **14 presentations** which list is provided as follows, along with the related public link on both INSIGHT and Health-Code websites (see ANNEX 3 for the agenda). The workshop got started with FCH2 JU and ECSEL JU program presentations which were held by their project officers.

- FCH2 & ECSEL Joint Undertaking Presentation (A. Aguillo-Rullan - FCH-JU; F. Ignacio - ECSEL-JU)
- Diagnostics, Prognostics and Control of FCS: Motivations, challenges and main issues (J. Mougin - CEA; C. Pianese - UNISA)
- Description of project HEALTH-CODE (C. Pianese - UNISA)
- Description of project INSIGHT (J. Mougin - CEA)
- EIS characterization of air- and O2-fed PEMFCs under five faulty operations (S.S. Araya - AAU)
- EIS, THD and PRBS characterization of SOFC under three faulty operations (B. Morel - CEA)
- HW and SW for on-board implementation of EIS (G. Petrone - UNISA)
- PEMFCs EIS-based diagnostics and implementation (M.C. Péra - UFC)
- Perturbation based SOFC diagnostic techniques (Đ. Juričić - IJS)
- Exploitation and market opportunities (D. Mazzella - Meta-SSERR)
- Role of diagnosis, monitoring, control and maintenance for EPS commercial product (L. Cantone - EPS)
- The Role of Monitoring and Diagnosis for Fuel cell Commercialization (K. Juelsgaard-Fløche - Ballard)
- Role of diagnostics and control on future SOC products for improved performance and durability (O. Bücheli - SOLIDPower)

Moreover, an extra presentation was held by Rolls-Royce:

- Real-time modelling of solid oxide fuel cell system for health monitoring and diagnostics (P. Wachel - Rolls-Royce)

4. Participants

The registration was handled by Absiskey. The registration was free of charge. The registration was made via online form at the link http://bit.ly/workshopfcdiagnostics2018 or via direct email to UNISA responsible.

The total registration number, before the workshop, was 67. The actual attendants were 58. The online-registered participants came from 15 different countries all over the world (see Figure 3). Their affiliation is shown in Figure 4. The list of registered attendants is in ANNEX 5.

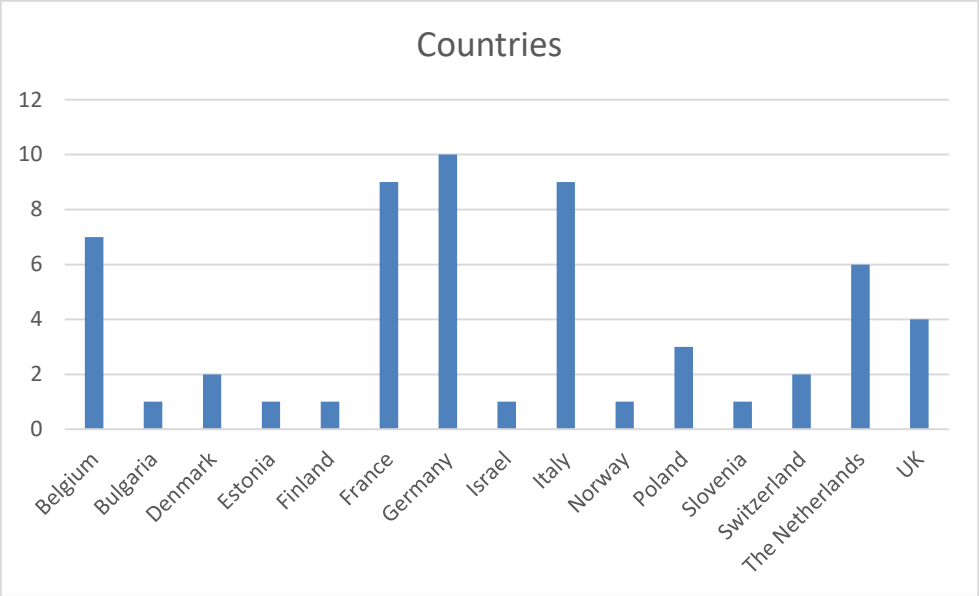

Figure 2 Attendants countries

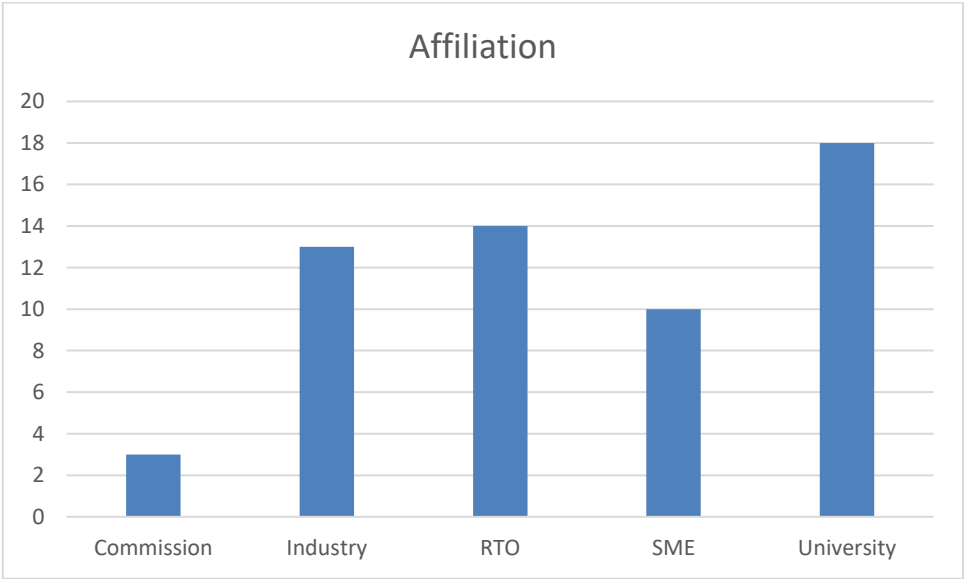

Figure 3 Attendants affiliation

Pictures of the event and its participants are showed in ANNEX 5.

5. Demo Presentation

During the workshop, the HEALTH-CODE main results were promoted (pictures below) along with posters illustrating the project results for both HEALTH-CODE and INSIGHT (see ANNEX 6). Copies of the Project flyer were also distributed to all the participants (see ANNEX 7).

Figure 4 EIS-box demo and posters

6. Interactive debate

At the end of the workshop, an interactive debate was held and conducted by Prof. Cesare Pianese. DirectPoll free tool was used to involve the attendants and allow them to answer questions directly via smartphone or webpage link. The participants could join the poll through the link/qr-code showed below.

http://etc.ch/X7DK

Figure 5 Link + qr-code for DirectPoll

The list of questions is listed below along with the answers.
ANNEX 8 shows the pictures related to the debate.

1. WITH RESPECT TO THE OPPORTUNITY OF IMPROVING FC TECHNOLOGY, HOW WOULD YOU RATE THE ROLE OF MONITORING DIAGNOSTICS & CONTROL TOOLS.	
HIGH	75.0%
MID	25.0%
LOW	0.0%
I DON'T KNOW	0.0%
2. HOW DIFFICULT DO YOU SEE THE IMPLEMENTATION OF THE HEALTH-CODE/INSIGHT MDC HW & SW WITH RESPECT TO CONVENTIONAL ONES?	
LOW	6.7%
MID	53.3%
HIGH	40.0%
I DON'T KNOW	0.0%

3. WOULD YOU BE WILLING IN PROMOTING/INVESTING IN THE SOLUTIONS PROPOSED BY HEALTH-CODE & INSIGHT?	
YES	63.3%
NO	16.7%
I DON'T KNOW	20.0%
4. WOULD YOU SUGGEST THE USE OF MDC TOOLS FOR OTHER FIELDS?	
ELECTROLYSERS	33.8%
REVERSE FUEL CELLS	26.5%
BATTERIES	29.4%
OTHERS	10.3%
5. WHICH REGION HAS THE GREATEST MARKET SHARE FOR THE MDC TOOL?	
NORTH AMERICA	19.6%
SOUTH AMERICA	2.0%
ASIA	41.2%
EUROPA	23.5%
AUSTRALIA & PACIFIC ISLANDS	3.9%
I DON'T KNOW	9.8%
6. ARE YOU SATISFIED WITH THE INFORMATION GATHERED AT THE WORKSHOP?	
YES	40.9%
I expected more TECHNICAL DATA	29.5%
I expected more SCIENTIFIC INFORMATION	18.2%
I expected more info on MARKET	11.4%
7. HOW WOULD YOU RATE THE CONTENT OF THE WORKSHOP?	
EXCELLENT	13.3%
GOOD	60.0%
AVERAGE	26.7%
FAIR	0.0%
POOR	0.0%
8. HOW WOULD YOU RATE THE PRESENTATIONS?	
EXCELLENT	3.3%
GOOD	53.3%
AVERAGE	40.0%
FAIR	3.3%
POOR	0.0%
9. HOW DID YOU KNOW ABOUT THIS EVENT?	
EMAIL	20.6%
WEBSITE	8.8%
COLLEAGUES	61.8%
OTHERS	8.8%

7. ANNEX 1 – Newsletter

Final Program

Workshop on Monitoring and Diagnostics of Fuel Cells

Innovative on-board diagnosis towards fuel cells performance enhancement

13 November 2018 – Brussels (B)

Manos Conference Center
Chaussée de Charleroi, 135 Bruxelles B-1060

registration: http://bit.ly/workshopfcdiagnostics2018
Info: http://pemfc.health-code.eu/ – http://insight-project.eu/

This is the last announcement for the Workshop on Monitoring and Diagnostics of Fuel Cells organized by the FCH2-JU funded projects **HEALTH-CODE** and **INSIGHT.** The Workshop will give an overview on the current status and the most recent advancements on monitoring, diagnostics and control of both **PEMFC and SOFC**.

The **final program with the list of speakers** is attached to this mail and available at the link.

A comprehensive overview and the exploitation potential of the projects results are offered to the interested stakeholders and users at various levels. Emphasis is given to methodological approaches for **advanced diagnosis** that can help achieving enhanced performance of both PEMFC and SOFC systems.

Invited guests from industry will offer a look into key topics tightly connected to monitoring and diagnostics of both PEMFC and SOFC. **Exploitation and market opportunities** of the projects results will be analysed and discussed with a representative from the European Commission Support Services for Exploitation of Research Results (SSERR).

A final open discussion among the attendees will be set to share experience and draft future paths towards FC improvements via on-board diagnostics. A **networking cocktail** has been organized for all registered guests.

For the registration to the Workshop please visit this page

Registration is free of charge; coffee, beverages and networking cocktail will be offered to all guests.

Please circulate this message to your colleagues interested on this topic.

Looking forward to welcoming you to the Workshop,

Best regards,

Julie Mougin (Coordinator of INSIGHT)
Cesare Pianese (Coordinator of HEALTH-CODE)

More Info: Final program
Venue: Manos Conference Center,
Chaussée de Charleroi, 135
Bruxelles B-1060 Brussels
Location

REGISTRATION

8. ANNEX 2 – PRD 2018 Flyer

9. ANNEX 3 – Agenda

pemfc.health-code.eu www.fch-ju.eu insight-project.eu

Workshop on Monitoring and Diagnostics of Fuel Cells

Innovative on-board diagnosis towards fuel cells performance enhancement

13 November 2018 – Brussels (B)

venue: Manos Conference Center, Chaussée de Charleroi, 135 B-1060
http://www.manosconference.com

registration: http://bit.ly/workshopfcdiagnostics2018

Info: http://pemfc.health-code.eu/ – http://insight-project.eu/

The workshop presents the current status and the most recent advancements concerning research on monitoring, diagnostics and control of both PEMFC and SOFC. It is jointly organized by the projects HEALTH-CODE and INSIGHT. Both projects provide advanced monitoring and diagnostic solutions towards improved performance, better management and maintenance scheduling, aiming at higher reliability and increased lifetime of PEMFC and SOFC technologies.

HEALTH-CODE focuses on developing an advanced Monitoring, Diagnostic and Lifetime Tool (MDLT) for μ-CHP and backup PEMFC systems equipped with air- and O2-fed stacks, respectively. Such a tool is based on the measurement of the Electrochemical Impedance Spectrum (EIS) while the stack is running in real operations. EIS allows the identification of FC current status to support the detection of five stack failure modes, as well as inferring on its remaining useful life.

The INSIGHT project aims at developing an MDLT for SOFC stacks based on EIS, Total Harmonic Distortion (THD) and Pseudo-Random Binary Sequence (PRBS) methods. The hardware necessary for its implementation into a real SOFC system is improved for on-board implementation of such approaches focusing on three different stack faults. The effectiveness of the MDLT is demonstrated through tests on a real micro-Combined Heat and Power system.

The workshop will gather engineers and researchers from industry, academia and research institutions interested in the most recent advancements on monitoring and diagnostic tools. Emphasis is given to methodological approaches for advanced diagnosis that can help achieving enhanced performance of both PEMFC and SOFC systems. A comprehensive overview and the exploitation potential of the projects results are offered to the interested stakeholders and users at various levels.

The workshop will start with an introduction on the EU Joint Undertaking for Fuel Cells & Hydrogen (FCH) along with a presentation of the EU JU ECSEL active in the field of Electronic Components and Systems. An overview of the projects will start the technical session; then, main results will be reported on the experimental activity and on various approaches for monitoring and diagnostics. Scientists and engineers from 15 teams will present their activities, bringing their knowledge, expertise and perspectives. Invited guests from industry will also offer a further look into key topics tightly connected to monitoring and diagnostics of both PEMFC and SOFC. Exploitation and market opportunities of the projects results will be analysed and discussed with a representative from the European Commission Support Services for Exploitation of Research Results (SSERR).

A final open discussion among the attendees will be set to share experience and draft future paths towards FC improvements via on-board diagnostics.

Registration is free of charge, please visit this page.

Coffee, beverages and networking cocktail will be offered to all guests.

The project HEALTH-CODE (Real operation pem fuel cells HEALTH-state monitoring and diagnosis based on dc-dc COnverter embeddeD Eis) has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under grant agreement No.671486. This Joint Undertaking receives support from the European Unions' Horizon 2020 research & innovation programme and N.ERGHY.
The project INSIGHT (ImplementatioN in real SOFC Systems of monItoring and diaGnostic tools using signal analysis to increase tHeir lifeTime) has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under grant agreement No 735918. This Joint Undertaking receives support from the European Unions' Horizon 2020 research & innovation programme and Hydrogen Europe and N.ERGHY.

pemfc.health-code.eu www.fch-ju.eu insight-project.eu

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registration: http://bit.ly/workshopfcdiagnostics2018

Info: http://pemfc.health-code.eu/ – http://insight-project.eu/

FINAL PROGRAM

Time	Topic	Speaker	Affiliation
13:00-13:20	**Registration, Coffee and Welcome**		
13:20-13:40	FCH2 & ECSEL Joint Undertaking Presentation	A. Aguillo-Rullan F. Ignacio	FCH-JU ECSEL-JU
13:40-13:50	Diagnostics, Prognostics and Control of FCS Motivations, challenges and main issues	J. Mougin C. Pianese	CEA UNISA
13:50-14:05	Description of project HEALTH-CODE	C. Pianese	UNISA
14:05-14:20	Description of project INSIGHT	J. Mougin	CEA
14:20-14:40	EIS characterization of air- and O2-fed PEMFCs under five faulty operations	S. S. Araya	AAU
14:40-15:00	EIS, THD and PRBS characterization of SOFC under three faulty operations	B. Morel	CEA
15:00-15:20	HW and SW for on-board implementation of EIS	G. Petrone	UNISA
15:20-15:40	**Coffee break**		
15:40-16:00	PEMFCs EIS-based diagnostics and implementation	M.C. Péra	UFC
16:00-16:20	Perturbation based SOFC diagnostic techniques	Đ. Juričić	IJS
16:20-16:40	Exploitation and market opportunities	D. Mazzella	Meta-SSERR
16:40-16:55	Role of diagnosis, monitoring, control and maintenance for EPS commercial product	L. Cantone	EPS
16:55-17:10	The Role of Monitoring and Diagnosis for Fuel cell Commercialization	K. Juelsgaard-Fløche	Ballard
17:10-17:25	Role of diagnostics and control on future SOC products for improved performance and durability	O. Bücheli	SOLIDPower
17:25-17:40	Real-time modelling of solid oxide fuel cell system for health monitoring and diagnostics	P. Wachel	Rolls-Royce
17:40-18:00	Discussion among guests, partners, participants	All	
18:00	Closure	J. Mougin, C.Pianese	CEA, UNISA
	Networking cocktail		

Registration is free of charge, please visit this page.

Coffee, beverages and networking cocktail will be offered to all guests.

HEALTH-CODE: AAU, Aalborg University (DK); AK, Absiskey (F); BPSE, Ballard Power System Europe (DK); BIT, Bitron Industrie S.p.A. (I); EIFER, European Institute for Energy Research (D); EPS ELVI ENERGY, Electro Power System S.p.A. (I); UFC, University of Franche-Comté (F); UNISA, University of Salerno (I).

The project HEALTH-CODE (Real operation pem fuel cells HEALTH-state monitoring and diagnosis based on dc-dc COnverter embeddeD Eis) has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under grant agreement No 671486. This Joint Undertaking receives support from the European Unions' Horizon 2020 research & innovation programme and N.ERGHY.
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10.ANNEX 4 – Registered Participants list

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11.ANNEX 5 – Photo Gallery

12.ANNEX 6 – INSIGHT posters

ImplementatioN in real SOFC Systems of monItoring and diaGnostic tools using signal analysis to increase tHeir lifeTime

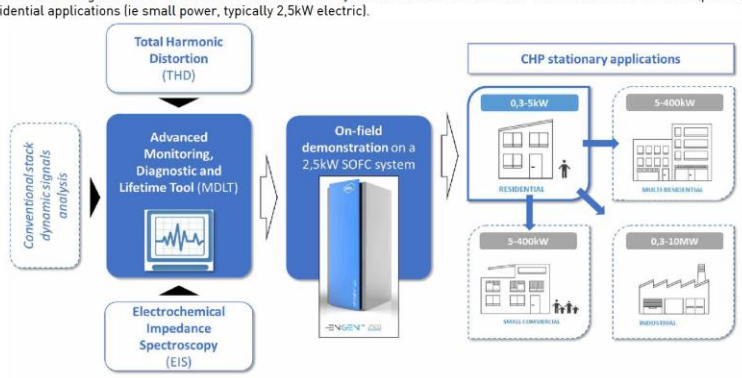
insight

START DATE	January 2017
DURATION	36 months
WEBSITE	www.insight.eu

FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

OVERVIEW OF THE GOAL

The INSIGHT project aims at developing a Monitoring, Diagnostic and Lifetime Tool (MDLT) for Solid Oxide Fuel Cell (SOFC) stacks. To achieve a cost-efficient and robust solution, two advanced complementary techniques will be exploited, Total Harmonic Distortion (THD) and Electrochemical Impedance Spectroscopy (EIS), in addition to conventional stack dynamic signals analysis. The project will implement prediction methodologies and demonstrate their effectiveness by on-field tests on a real micro-Combined Heat and Power (μ-CHP) system for residential applications (ie small power, typically 2,5kW electric).



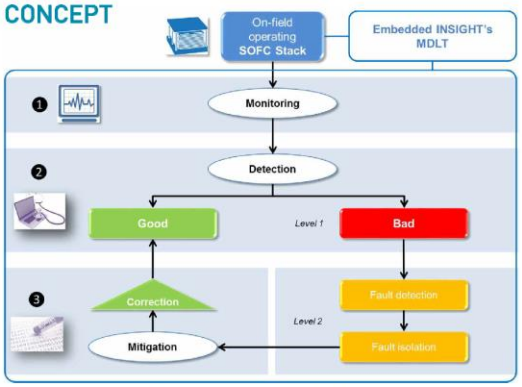
MAIN OBJECTIVES

To implement an advanced **Monitoring, Diagnostic and Lifetime Tool** to prolong SOFC lifetime by 5% and increase availability by 1%.

To develop the **hardware for the implementation** of advanced Monitoring, Diagnostic and Lifetime algorithms on real SOFC system with **low cost** (less than 3% of system cost).

To identify control actions able to **mitigate** the impact of both **degradation mechanisms and faults** on performance and durability of SOFC.

CONCEPT



INSIGHT concept to prolong the stack State-of-Health (SoH), hence prolonging Lifetime and increasing the SOFC system's availability.

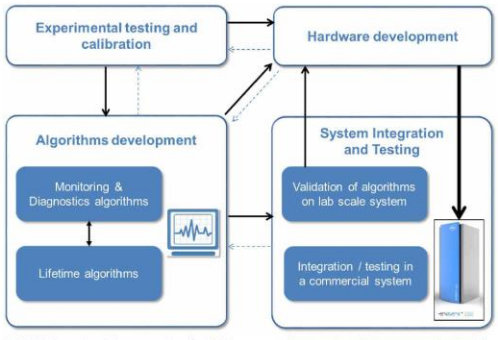
The INSIGHT project will develop both hardware components and algorithms to monitor, detect and finally correct defects that can occur in SOFC stacks. This will help to increase the durability and reliability of SOFCs systems, and at the same time decrease their total cost of ownership, by decreasing the needs to change the stacks and thus the maintenance costs.
To achieve and maintain a good State of Health (SoH) of the stack over long operating time, the INSIGHT concept is based on the following steps:

Monitoring: it will generate a set of data, which needs to be further analysed and treated.

Detection and isolation of faults based on two levels of diagnostics using EIS / THD and conventional stack signals analysis applied on the set of data provided by monitoring.

Mitigation and correction: it will apply corrections or mitigation strategies on the degraded system to recover a good SoH or at least increase its remaining operating time upon conditions which are not nominal but still acceptable.

METHODOLOGY



INSIGHT's methodology overview (solid lines mean inputs, dotted lines mean feedback).

The INSIGHT project will implement methodologies merging experimental approaches and mathematical techniques to develop two types of algorithms:
- algorithms suitable for monitoring, fault detection and isolation, aiming at identifying the metrics of major interest ;
- algorithms to estimate stack SoH and lifetime, supported by modelling tasks linking the degradation to its causes.

The coupling of both types of algorithms on-board will allow proposing mitigation strategies to recover a good, better, or at least stabilised SoH of the stack. The so-called Monitoring, Diagnostic and Lifetime Tool (MDLT) will be firstly validated on a laboratory scale system. This MDLT will be embedded into a hardware made of a single board, which will be coupled to the power electronic and finally integrated into a commercial μ-CHP system, the EnGenTM 2500 from Solid Power. This modified system will be tested on-field to be representative of the real future operation.

PARTNERSHIP

cea · DTU Technical University of Denmark · IJS · EPFL ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE · VTT · BITRON · SOLID POWER · absiskey · AVL · HTceramix HTceramix SA, a SOFCpower subsidiary

insight

insight

ImplementatioN in real SOFC Systems of monItoring and diaGnostic tools using signal analysis to increase tHeir lifeTime.

START DATE JANUARY 1ST 2017
DURATION 36 MONTHS

Objectives

Stacks lifetime +5%

Availability +1%

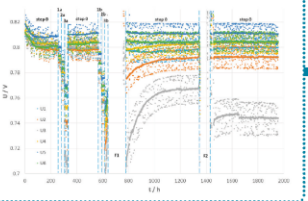
Total Cost Ownership -10%/kWh

EXPERIMENTAL TESTING AND CALIBRATION

SOFC 6-cells short stack from SOLIDpower tested at CEA in collaboration with IJS.

Fuel starvation has been gradually tested with EIS and PRBS measurements implemented every 6 h during 2000 h of test.

step 0 - FU=77.4% nominal operating conditions 750°C, i=0.4 Acm-2
1a - FU=82.4% by decreasing H2 flow rate
2a - FU=87.4% by decreasing H2 flow rate
3a - FU=92.4% by decreasing H2 flow rate
1b - FU=82.4% by increasing current
2b - FU=87.4% by increasing current
3b - FU=92.4% by increasing current
F1 - OCV after H2 supply shutdown
F2 - OCV after H2 supply shutdown



HARDWARE DEVELOPMENT

The project hardware includes a dedicated ECU, called Bitron Box, currently under development.

First release is planned for September 2018.

The main architecture consists of:

- An embedded Linux board (Beagle bone Black v3) to run high level algorithms.
- A dedicated custom board (Bitron board) dedicated for data sampling and conversion, equipped with:
  - Analog input filters for noise attenuation.
  - Four acquisition channels: two used for acquiring DC signals and two for AC signals.
- STM32F4 microcontroller equipped with an ARM Cortex M4 core and a maximum clock frequency of 168 Mhz.
- Extended RAM module for increasing the number of data samples buffered before the post-processing part.

The ADC conversion, made with a 24bit resolutions Sigma Delta device by Texas Instruments, runs at a maximum sampling rate of 75kSps.

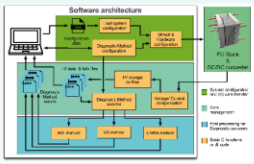
The overall system communicates over a TCP protocol to exchange commands and data between the components of the system.

The final objective of the proposed system is to provide an "on site" device to increase the quality of the analysis minimizing production costs. Therefore, demonstrating its reliability and affordability for an industry use, which nowadays, is limited by costly laboratory instrumentations.

ALGORITHMS DEVELOPMENT

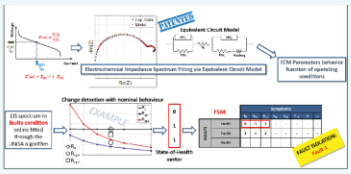
Monitoring and Diagnostic Tools

UNISA is developing a diagnostic algorithm for Detection and Isolation of faults at single cell and stack level based on Electrochemical Impedance Spectroscopy. The algorithm follows a generic and fast fitting technique to extract Equivalent Circuit Model (ECM) parameters to map offline both nominal and faulty states of the system. This helps in designing reference patterns through which fault detection is performed. Indeed, online EIS measurements are used for real time estimation of ECM parameters, then compared with their nominal mapped values. If a sensible divergence occurs, a symptom arises. Symptoms collection and comparison with faulty patterns allows afterwards State-of-Health estimation.



The Linux-based board sends acquisition commands to the Bitron board. Once the acquisition is completed the data samples are stored as binary files on the Linux-based board. Those data files are used in a second time for the elaboration process by the algorithms developed by all the partners. The aim here is to create a sort of interface which can be interpreted as a standard for all the working algorithms. The selected approach allows to minimize each Software modules complexity which are independent. Furthermore,they can be easily tested and validated creating "ad hoc" test suites with the objective to guarantee robustness and reliability.

The figure shows the schematics of the high level (HL) software; it has been conceived to include EXTERNAL CODE that takes as input the acquired data for performing on the Linux-based board the diagnostic methods.

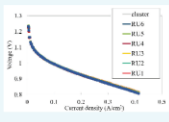


Validation of algorithms on lab scale system

EIS signature identification for fault detection – RU4 3mm missing sealing (EPFL)

Leakage due to missing sealing close to the flow outlet is difficult to detect.
From i-V curves no difference in:

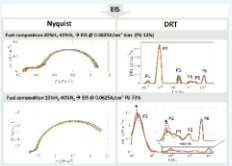
- OCV
- performancesamong the different RUs

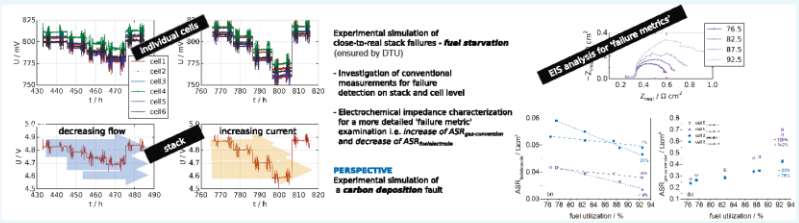


No difference are detected even by EIS with nominal fuel flow operation at low current density.

Changing operating conditions can improve fault detectability.

By increasing the conversion rate the DRT analysis shows a shift of the gas conversion peak (P2) and an increase of the resistances of the anode diffusion process (P3) of the faulty element if compared with the healthy elements.





Lifetime Tools

Instead of conventional sine-based EIS evaluation, IJS is coming up with a much more efficient alternative relying on non-sinusoidal perturbation in terms of step-like pseudo-random binary signal (PRBS).

Features:

- high resolution of the evaluated EIS curve
- required time to run the experiment is by 10 times shorter than in conventional EIS
- even suitably exciting current during normal operation may suit to identify the model and hence characterise the system, the optimal model structure can be inferred from data
- the scheme is presently applicable to a serial connection of QR elements.

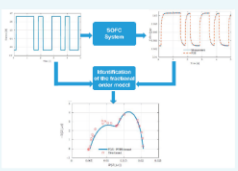


Fig.1: From non-sinusoidal excitation to SOFC model. Below is the comparison between conventional sine-based EIS (circles) and PRBS-based EIS (solid line).

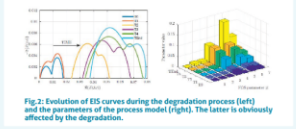


Fig.2: Evolution of EIS curves during the degradation process (left) and the parameters of the process model (right). The latter is obviously affected by the degradation.

SYSTEM INTEGRATION AND TESTING

Integration / testing in a commercial system

This project has received funding from the Fuel Cells and Hydrogen Joint Undertaking (FCH JU) under grant agreement No 735918. This publication reflects the views only of the author, and the FCH JU cannot be held responsible for any use which may be made of the information contained therein.

Contact us if you want to be the first to be informed about latest results of the project. Follow INSIGHT on the website : www.insight-project.eu

13.ANNEX 7 – INSIGHT flyer

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The INSIGHT cost-efficient and robust solution will exploit two advanced complementary techniques:
- Total Harmonic Distortion
- Electrochemical Impedance Spectroscopy

in addition to conventional stack dynamic signals analysis.

The effectiveness is demonstrated by prediction methodologies and on-field tests on a real micro-Combined Heat and Power (μ-CHP) system for residential applications (ie small power, typically 2,5kW electric).

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14.ANNEX 8 – Debate pictures

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