Degradation Signature Identification for Stack Operation Diagnostic (256693)

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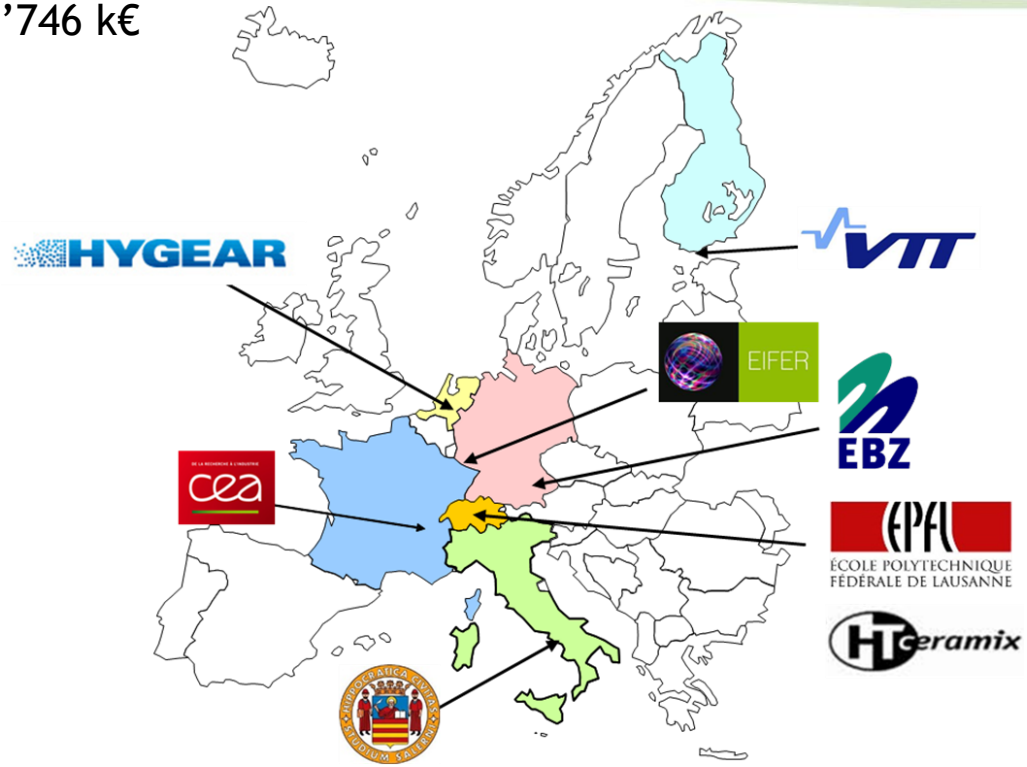
Design Partnership & Budget

3 years collaboration project:

01-01-2011 to 31-12-2013

Total budget: 3'266 k€ - Total funding: 1'746 k€

Participant	Country	Type
CEA	France	R&D
VTT	Finland	R&D
Eifer	Germany	R&D
UNISA	Italy	University
EPFL	Switzerland	University
HFCS	Netherlands	Industry/SME
HTc	Switzerland	Industry/SME
EBZ	Germany	Industry/SME



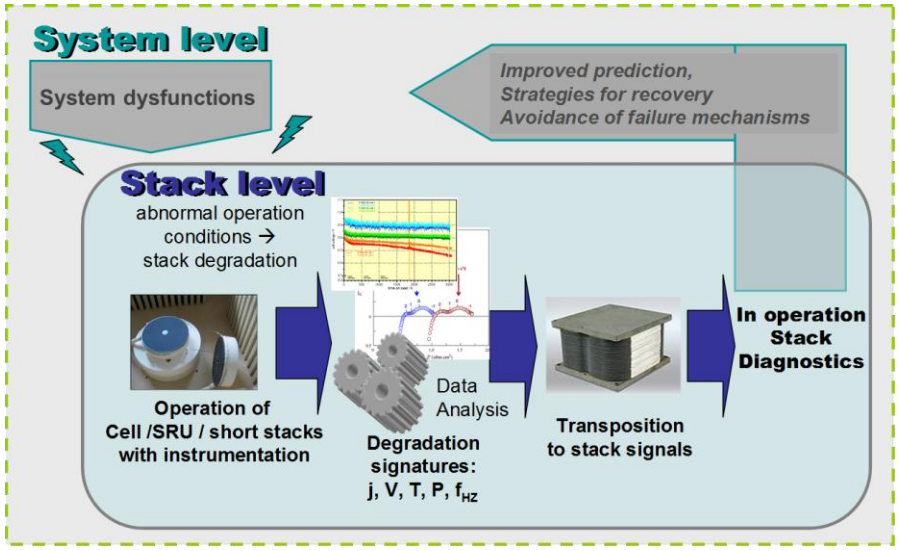
A European dimension with
a good balance between academics, R&D centres and industries

Design Concept & Targets & current status

Overall objectives of the DESIGN project:

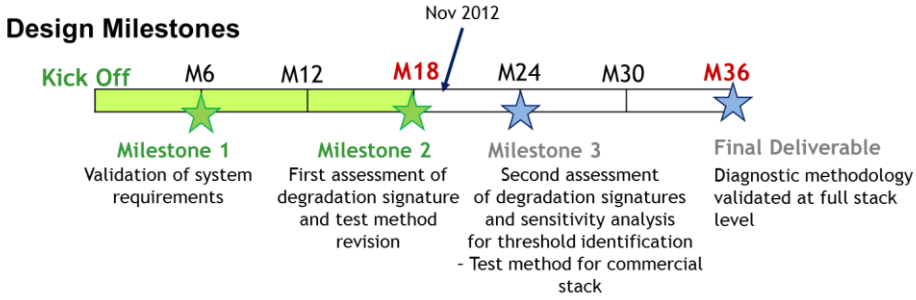
→ through **the understanding of the local responses of sub-stack elements**

→ provide **a sound diagnostic method for insidious phenomena** that slowly accelerate the degradation at the commercial stack level,

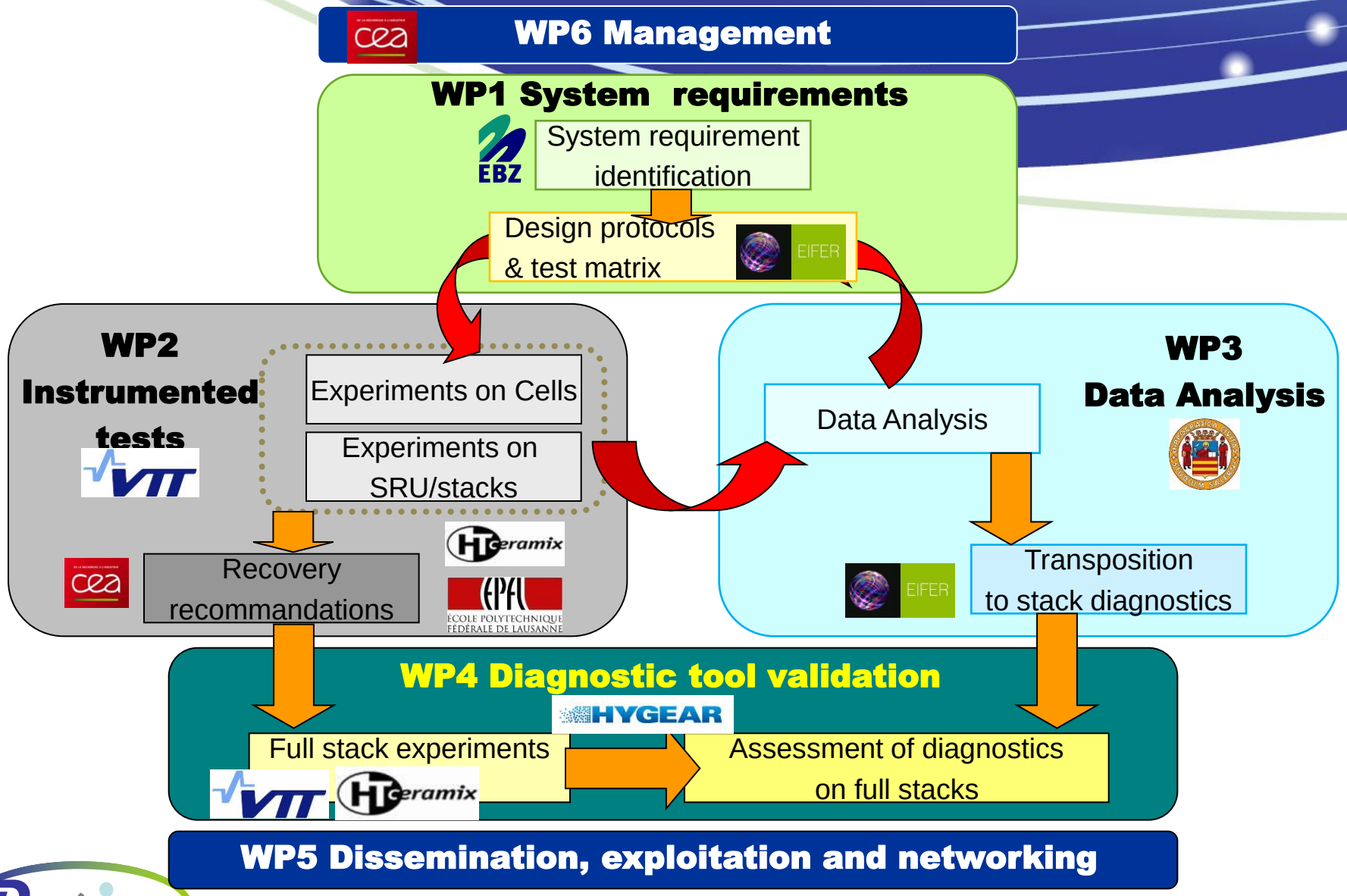


1-Identification of:
- **specific signatures at the local** cell / SRU / small stack level
- **data analysis methodology**

2-**Transposition** from **local** signatures to **full stack** with limited instrumentation



Project Organisation



Selection of Degradation Mechanism

Review of major **system dysfunction** & associated **degradation mechanism** and and analysis of their criticity on the basis of an HAZOP approach (summary available on www.design-sofc-diagnosis.com) → **~15 cases analysed**

Degradation phenomena to be studied in DESIGN:

- have a clear signature
- can be distinguished from other degradations
- have a potential of at least partial recovery

Those related to transient operation → not considered

→ Selection of most critical system dysfunction and degradation mechanism (occurrence and severity) to be investigated:

1) Anode re-oxidation by locally increased fuel utilizations

2) Carbon deposition

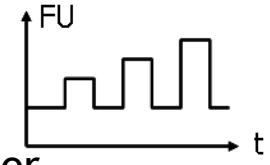
3) Small leakage at anode side

Test protocols & test matrix

- **Nominal testing conditions identified:**
  - Fuel composition as recommended in FCtestQA for internally steam pre-reformed methane at 10% (14% CH_4, 6% H_2, 28% H_2O, 1,8% CO_2, 50% N_2 …)
  - Initial furnace temperature **750°C**
  - Current density **0.5 A.cm^{-2}** for ASC and 0.3 A.cm^{-2} for ESC
  - Gas Flow to target **FU of 60%**

Hydrogen

- **Excursion to emphasize degradation mechanisms** (on single cell, SRU and instrumented short stacks)
  - **For High fuel utilization:** progressive increase of current density or decrease of fuel inlet up flow to reach 90% FU
  - **For carbon deposition:** progressive decrease of S/C ratio and/or decrease of current density
  - **For leakage:** technological study on going to implement a controlled, and reproducible leakage



Design Technical Accomplishment
First test Campaign

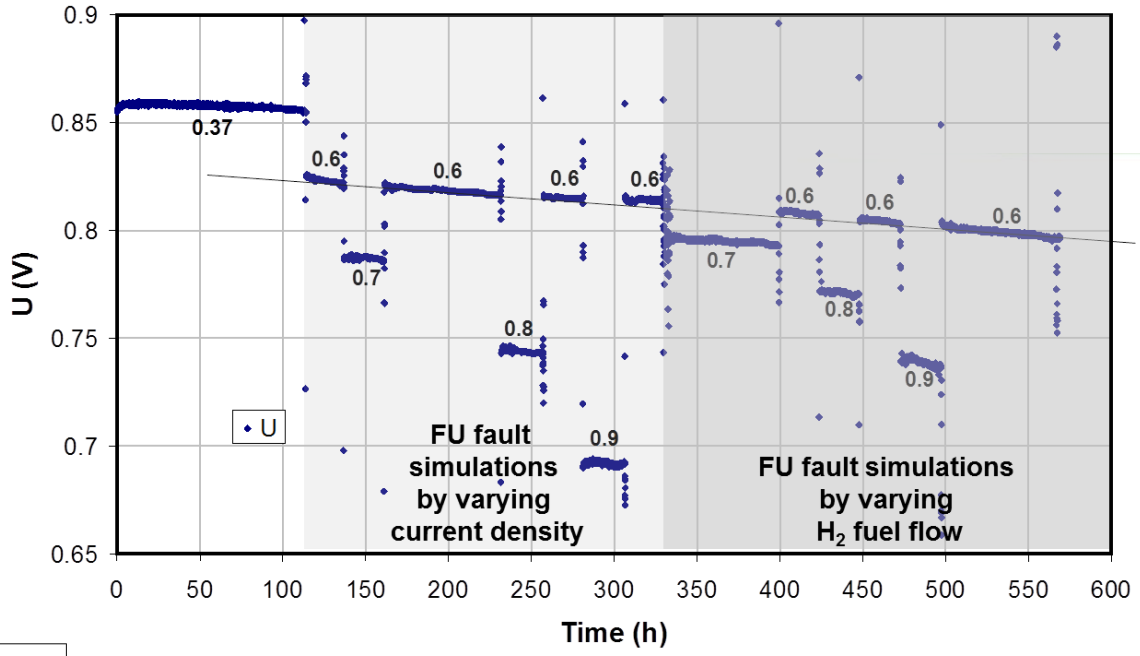
- 13 successful full protocols achieved under hydrogen to characterize high fuel utilization fault

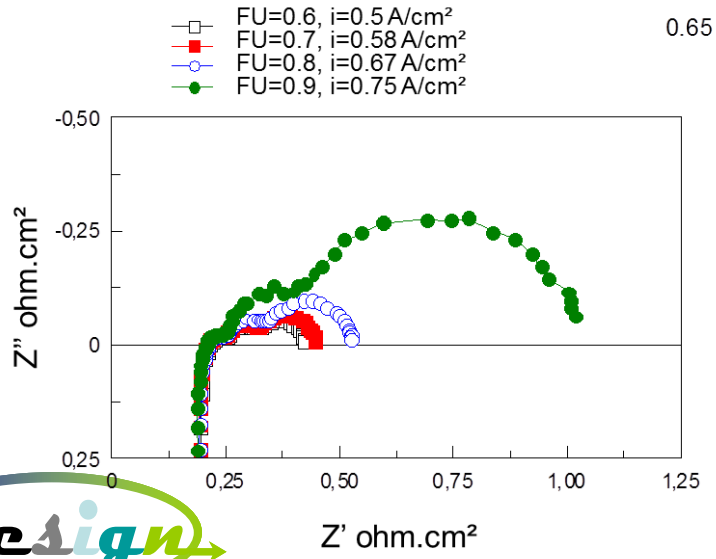
	Protocol 1: Increase of current density	Protocol 2: Decrease of flow rate
Single Cells	5	4
SRU	1	1
Short Stack	1	1

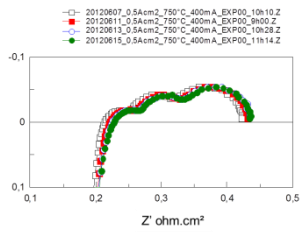
→ Satisfactory signals, consistency between testing partners and between scales

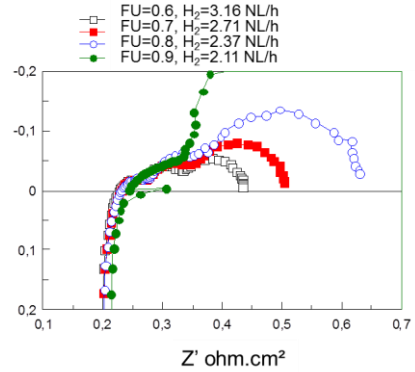
Design Technical Accomplishment

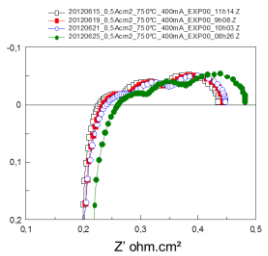
Ex of single cell behaviour









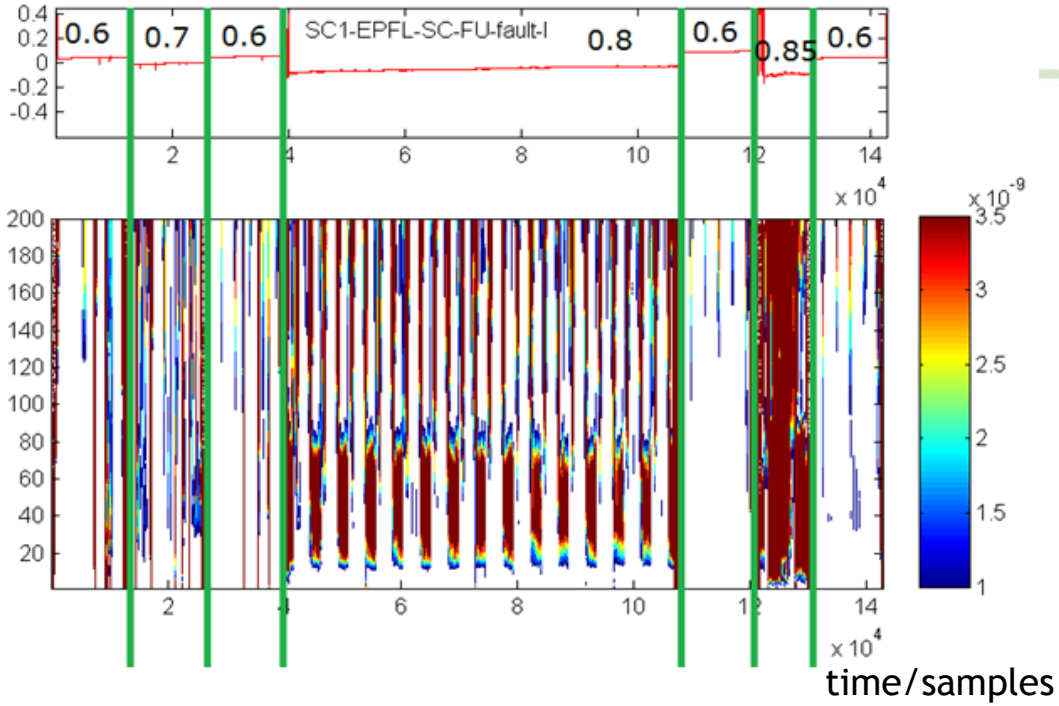


Data Analysis Methodology (1/2)

CWT of the voltage signal, with **coefficient scale** varied from 1 to 200 for all contour plots and

color bar scale giving the value of the coefficient (the higher the value, the higher the similarity of wavelet and signal)

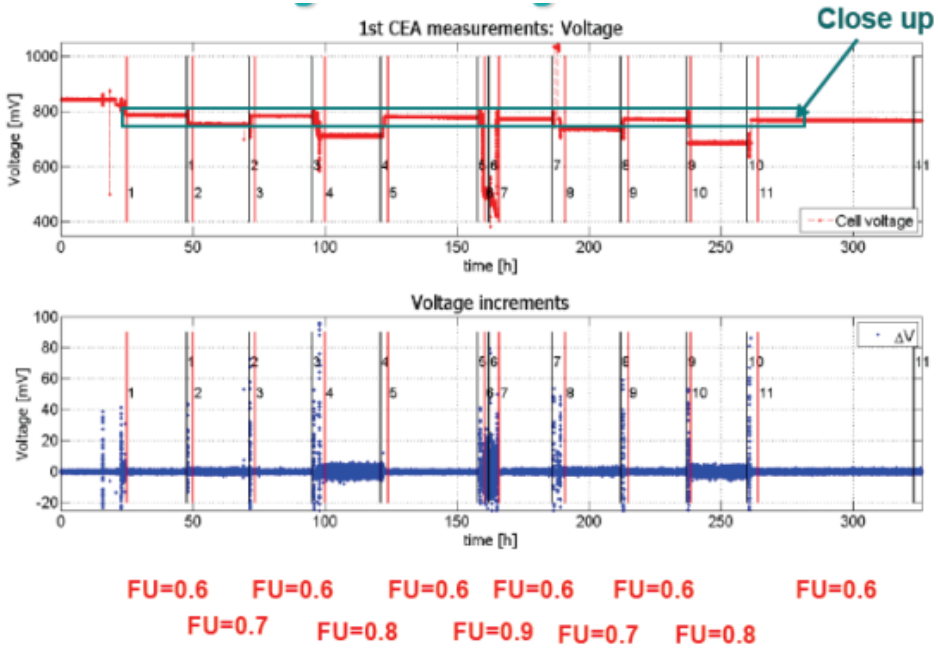
Coefficient pattern very similar for given FU → **signature** of a high FU. (Upon publication)

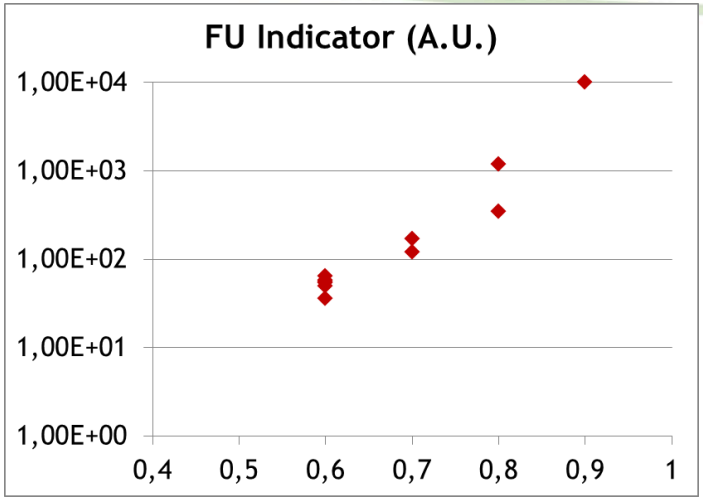


Using scale analysis technique, wavelet analysis (Continuous Wavelet Transform CWT) shows high capability to detect the **FU changes**.

→ The Wavelet Coefficients are a possible signature of FU changes

Design Technical Accomplishment
Data Analysis Methodology (2/2)





Upon patenting

Mathematical treatment of the time varying voltage signal, shows high capability to support the **FU changes detection analysis:**

→An indicator value has been identified that can be used as a signature of FU changes

Design Technical Accomplishment
Summary vs AIP 2009

Expected output **AIP 2009 Topic: 3.3** **Call: 2009**	Project Objectives	Status at 50% of the project	Expected revised objectives
Novel diagnostics to identify potential failures, including in-operation diagnostic tools for cell/stack	**Set of characteristic signatures** monitored **during operation** and related to specific degradation phenomena.	Selection of **3** relevant critical dysfunctions (over 15) to be studied Identification of **signatures of high FU dysfunction** (publication-patent)	Focus given on 1 dysfunction and associated degradation mechanism to assess it and validate it on commercial stacks
Improved prediction and avoidance of failure mechanisms			
Tools for improved diagnostics and services			
Tools for improved diagnostics and services	**Recommendations for recovery strategies.**	*not started yet*	for high FU dysfunction

Design Technical Accomplishment
Summary vs MAIP

Expected output MAIP - AA3 Stationary Power Generation & CHP	Project Objectives	Status at 50% of the project	Expected revised objectives
Achieve the principal technical and economic specifications necessary for stationary fuel cell systems to **compete with existing and future energy conversion technologies**	Development of a **Diagnosis methodology** like in other mature competing techno	**Development of a diagnosis methodology for high FU detection**	*Validation of the **diagnosis methodology for high FU** on **commercial stacks***
Deliver **reliable control and diagnostics tools** both at a component and at system level	Main objective of the project		
Include the **use of multiple fuels**	**H_2 and reformate**	**H_2**	*H_2 and reformate*
Include a **lifetime increase up to 40,000h**	Recovery strategy		Recovery strategy

Education, Training & Dissemination

Education & Training:

1 PhD student funded at UNISA, who has spent time at partners laboratories (EIFER)

Organisation of workshops:

☺ *Workshop 1, M3: to determine the most probable and the most critical events for the stack operation to be studied in the project with industry partners (SOFC system & cells and stack providers)*

• Workshop 2, M24-M30: with sensor producers or integrators to collect knowledge of State of the Art sensors that are easy to integrate and cost effective, applicable to SOFC diagnostics. Linked with industrial event.

• Workshop 3, M30-36: Dissemination and exploitation workshop (SOFC system & stack providers)

www.design-sofc-diagnosis.com

Technology transfer and collaboration

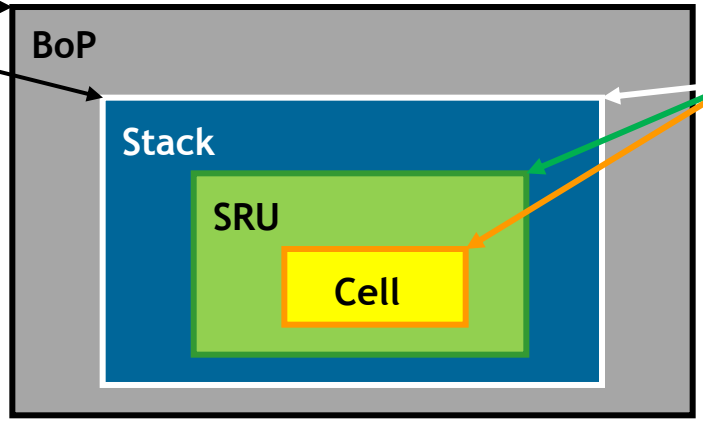
- **Collaborations**

GENIUS

Subject: System

Sensor: Stack

Outcome: diagnostic tool



DESIGN

Subject: Stack

Sensors: Various levels

Outcome: Method & signatures as inputs to a diagnostic tool

+ recovery strategies recommendations

- **Technology Interfaces**

➡Enhanced interface between SOFC manufacturers and signal treatment specialists and sensors producers

Design Future perspectives

Project Future Perspectives

- Need/opportunities for international collaboration
  - High: Sharing fundamental approaches and understanding can accelerate the identification of relevant signals /signatures and the development of adapted sensors for diagnostic
- Possible contribution to the future FCH JU Programme
  - Development of a diagnosis hardware integrated into a commercial stacks for high FU dysfunction,
  - Extension of the approach to other "relevant" dysfunctions

    Design is focused on ~~3~~ 1 degradation mechanism when some 15 ones have been listed (including transients ones); identifying the signatures from cells to stack and to system of these 15 degradation mechanisms remain challenging and deserves more effort