



DC/DC Converter-based Diagnostics for PEM systems (256673)

Start date: March 1, 2011

www.d-code-jti.eu

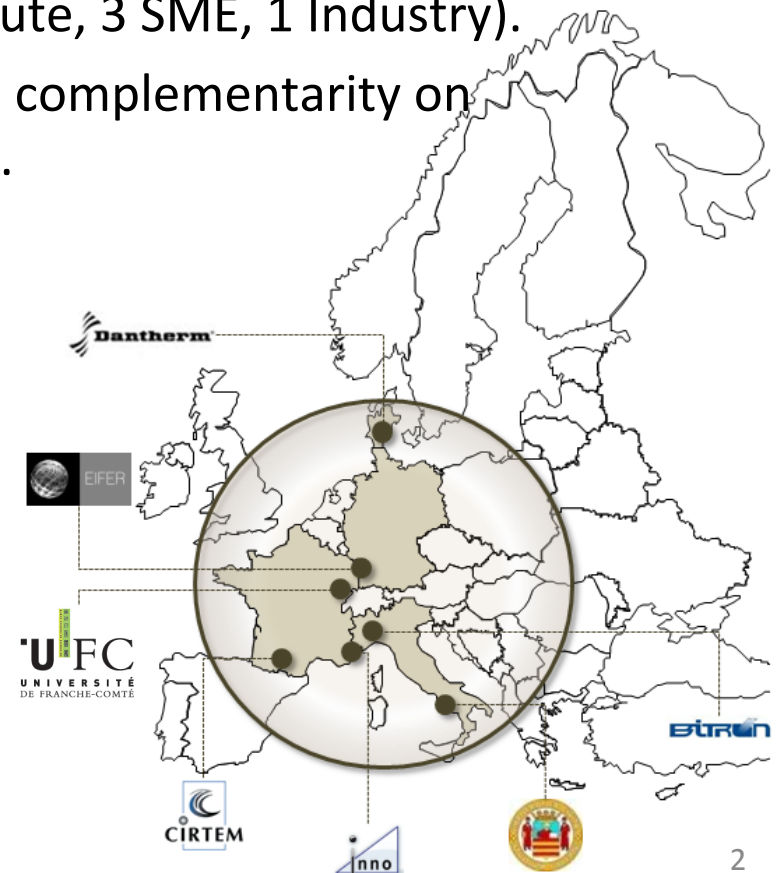
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November, 2012



- 36 months 01-03-2011 to 28-02-2014
- Budget 2.215 M€ - Funding 1.173 M€
- 7 partners from 4 countries representing a good mix of EU research and technology actors (2 Universities, 1 Research Institute, 3 SME, 1 Industry).
- Large experience in each area of interest with high complementarity on PEMFC, power electronics, diagnostics and control.

Partner - short name - country		Type
University of Salerno	UNISA-I	Univ.
Eur. Inst. for Energy Research	EIFER-D	Res.
Université de Franche-Comté	UFC-F	Univ.
Dantherm Power A/S	DANTH-DK	SME
CIRTEM	CIRTEM-F	SME
Bitron S.p.a	BITRON-I	Ind.
Inno TSD	INNO-F	SME



Project achievements 1/7

objectives

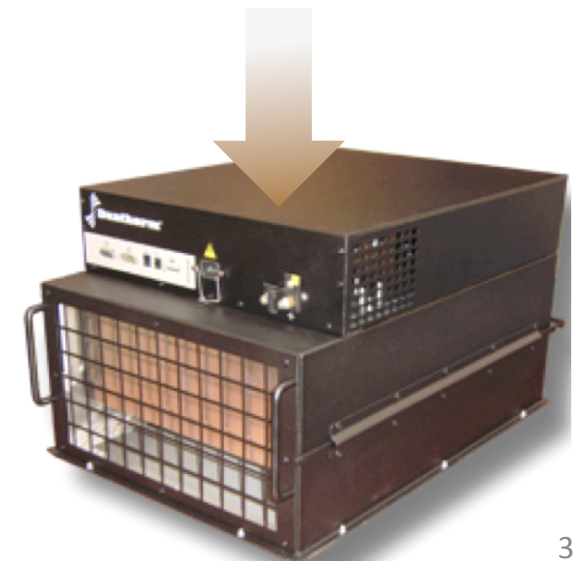
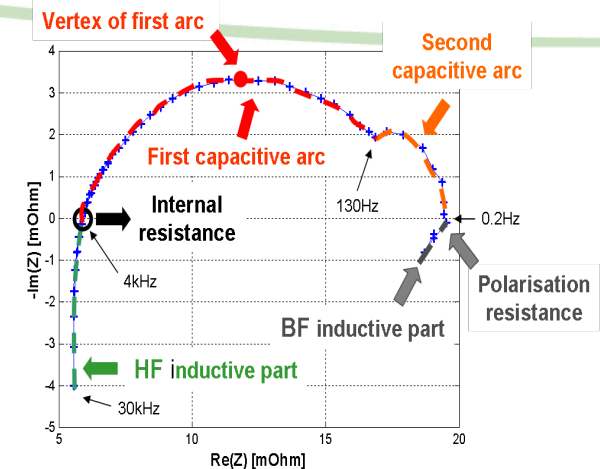


Main objectives:

- Development of two **DC/DC converters (LV/HV)** for **Electrochemical Impedance Spectroscopy diagnosis** to be installed on-board of **LT and HT fuel cell systems**.
- Transpose **EIS from lab scale to on-field** applications for **monitoring and diagnosis**.
- Development of the power stage and control strategy of a **DC/DC converter to obtain the stack impedance spectrum on-board**.

Enhancements w.r.t. DoW:

- Two converters (LV/HV).
- Flexible EIS board decoupled from the converter.
- Wider and improved quality experimental database.
- Off-line/OCV diagnosis method.





Main concepts:

- EIS collects significant information in a **single mathematical representation** guaranteeing a **holistic analysis** of the stack.
- **On-board EIS** and available BoP measurements will guarantee a **complete analysis** of the **FC state** while running **on-field**.
- The diagnostic system will **detect the faults** and identify the main sources for critical operations **with a deeper comprehension of relationships among causes and effects**.



Main targets:

Diagnose the FCS for a realistic assessment of Stack & BoP status.

Support the management system for:

Monitoring and failure prediction; Forecast lifetime; Control strategy adaptation; Dynamic response improvement; Fault recovery; Maintenance planning; Ensuring system readiness and system reliability; Activate alarms for regulation purposes.



Project achievements 3/7

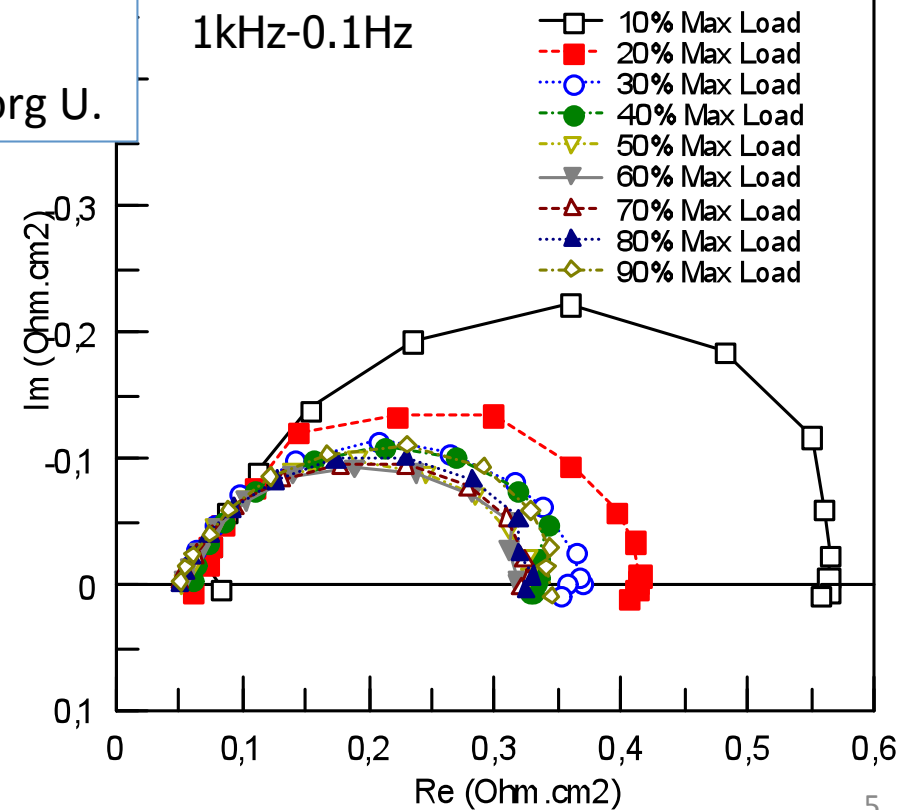
WP 2 EIS-characterization of LT/HT FC stack in system



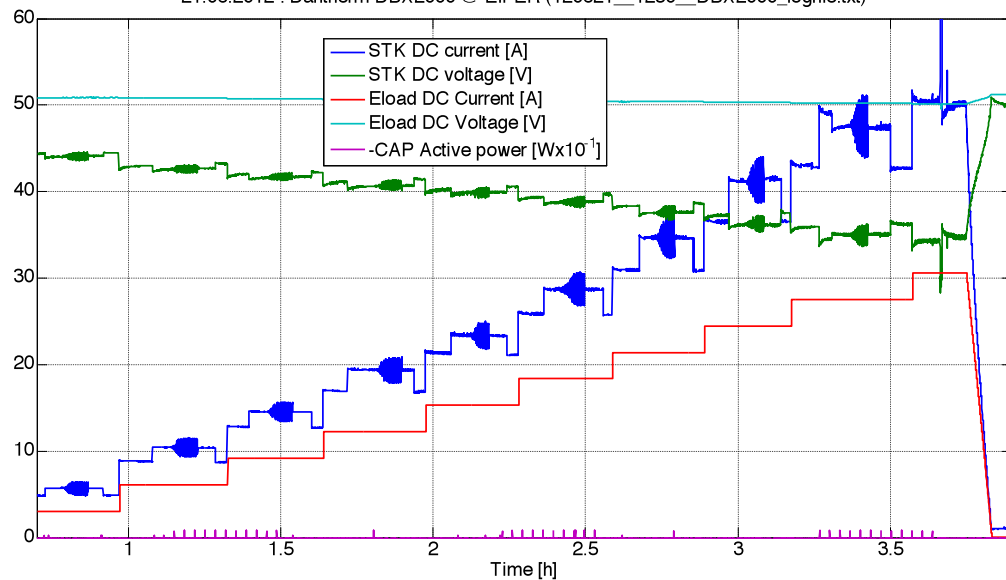
- EIS stack's mapping for LT & HT FCS
- Remove the BoP effects on EIS curves
- Cooperation with Fraunhofer and Aalborg U.

21.06.2012: EIS on DBX 2000 system

1kHz-0.1Hz



21.06.2012 : Dantherm DBX2000 @ EIFER (120621__1230__DBX2000_logfile.txt)



Project achievements 4/7

WP 3 EIS-oriented DC/DC converter

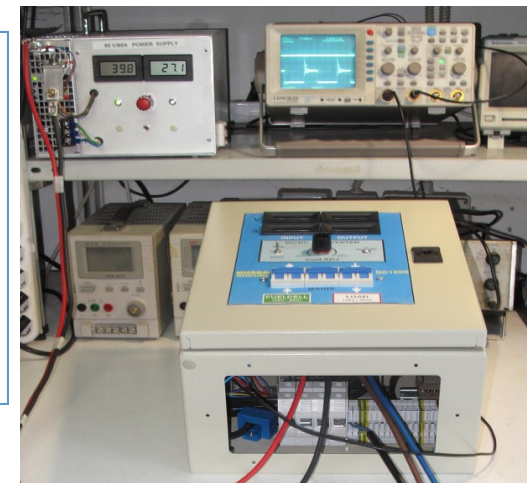


- Design, implement and optimize two reliable, high efficient DC/DC converter for HV and LV fuel cells.
- Perform the Electrochemical Impedance Spectroscopy via external DC/DC controller.
- Easy interfacing of the EIS board with any converter.

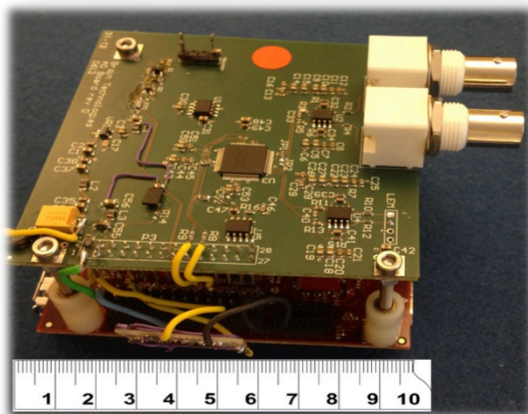
HV DC/DC converter under testing



LV DC/DC converter under testing



EIS board
Converters' driver



EIS software developed and tested:

- ✓ FFT algorithm
- ✓ Noise rejection tested
- ✓ Loopback tested

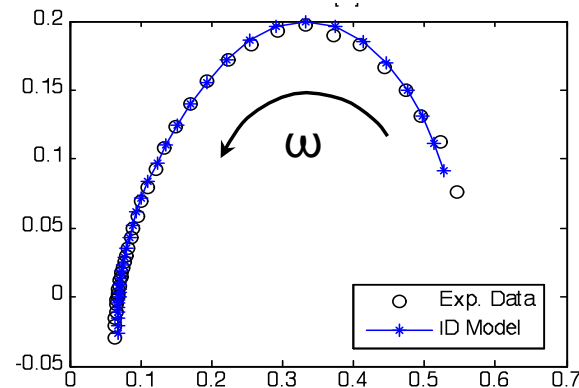
Project achievements 5/7

WP 4 Diagnosis algorithm development 1/2

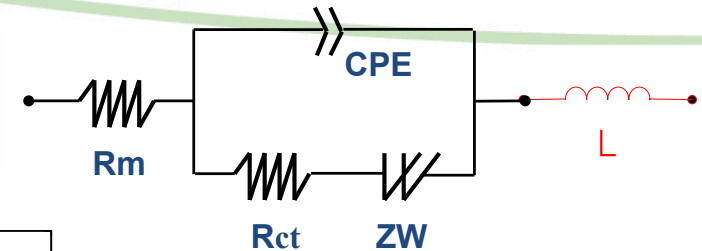


- Diagnostic schemes for LT and HT PEMFC systems.
- Implement algorithms for faults detection and faulty process identification.
- Stack status detection.
- Three methodologies have been Implemented:
 - Model (RLC).
 - Knowledge based (Fuzzy Clustering).
 - Artificial intelligence (Adaptive Neuro Fuzzy).
- Successful tests have been performed.

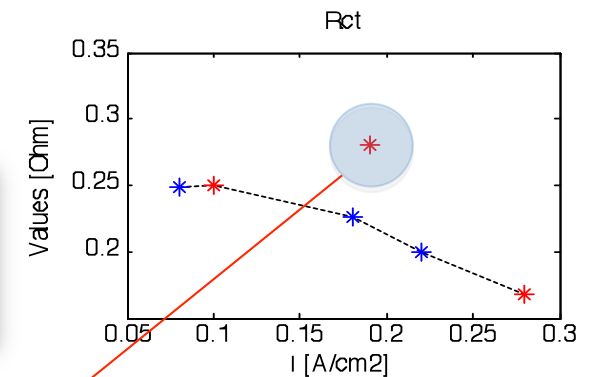
RLC model-based monitoring algorithm



Detect parameters' deviation from expected ones and make inference



Reconstruct the EIS spectrum from experimental data

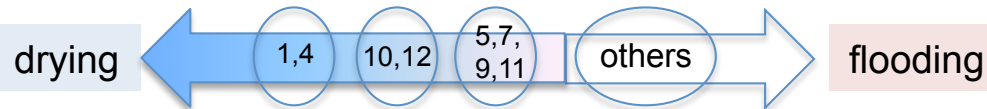
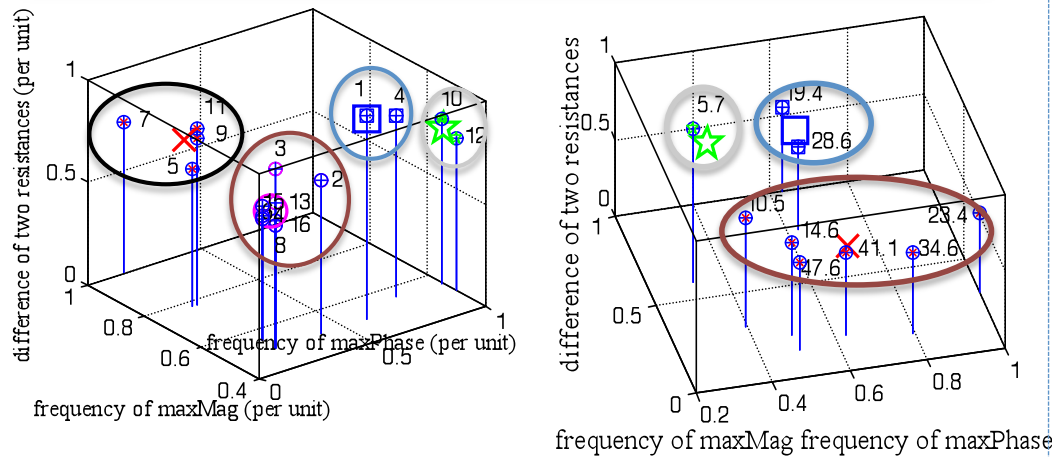


Anode drying may have started



Fuzzy Clustering with automatic feature selection

Two data sets

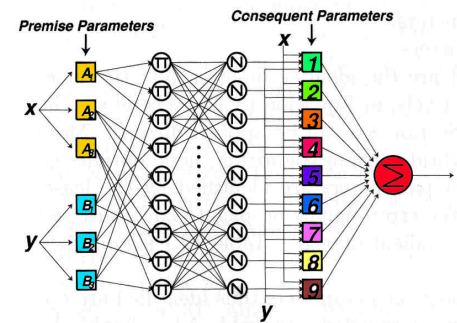


Classification of different conditions for two data sets (UFC, D-CODE).

4 and 3 clusters represent different degrees of drying or flooding.

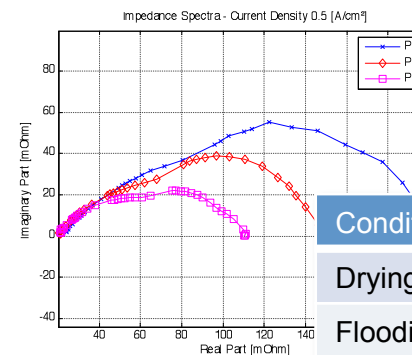
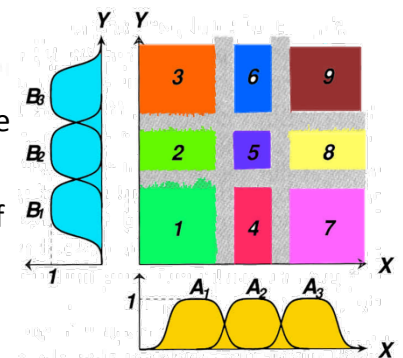
Common features for the two fuzzy clustering.

Adaptative Neuro-based Fuzzy Inference



After Wasterlain PhD thesis - FCLab

input layer → fuzzification → F-rule
 → output membership function
 → Defuzzification → summation of all outputs



50 mHz to 5 kHz

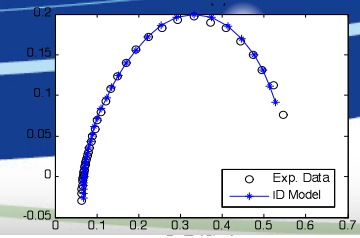
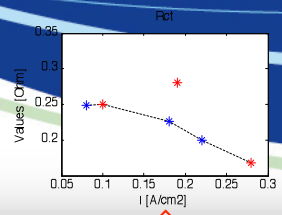
Condition	Total	Ok	Failed	Effect
Drying out	43	22	21	51%
Flooding	43	12	25	42%
Normal	43	28	15	65%
Total	129	58	61	45%

Project achievements 6/7

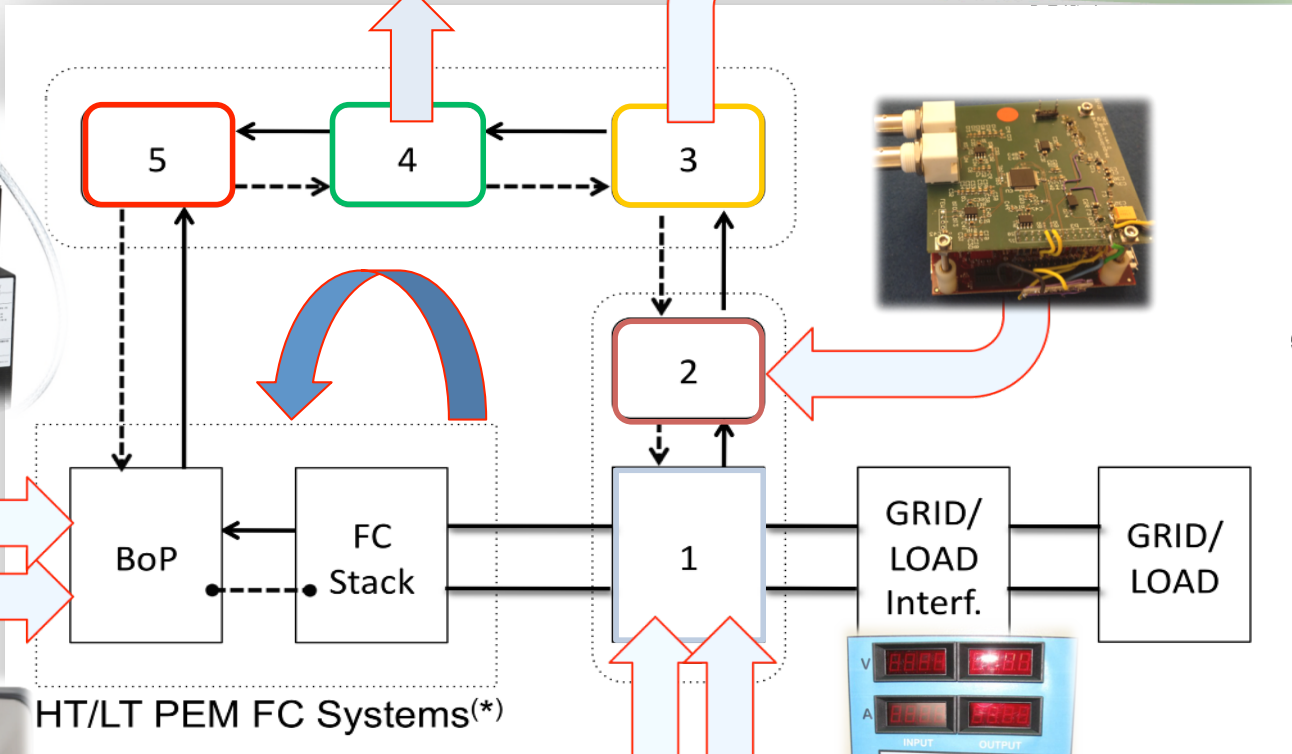
WP 5 Implementation of EIS and control in FCS



Diagnosis

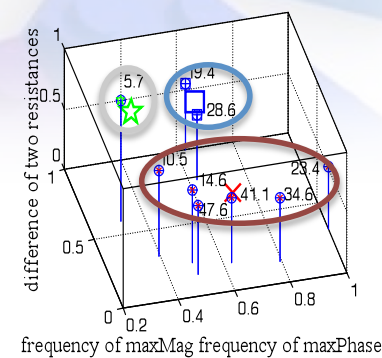
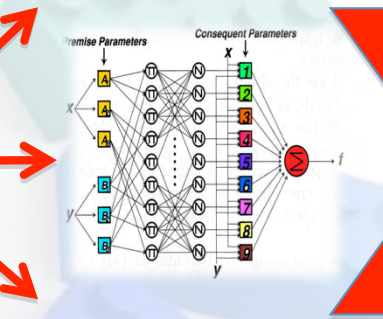
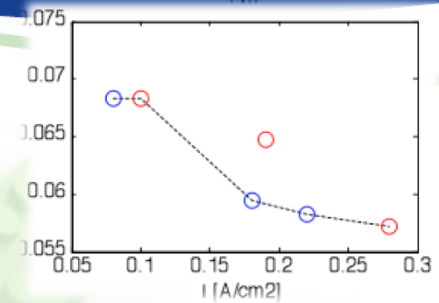
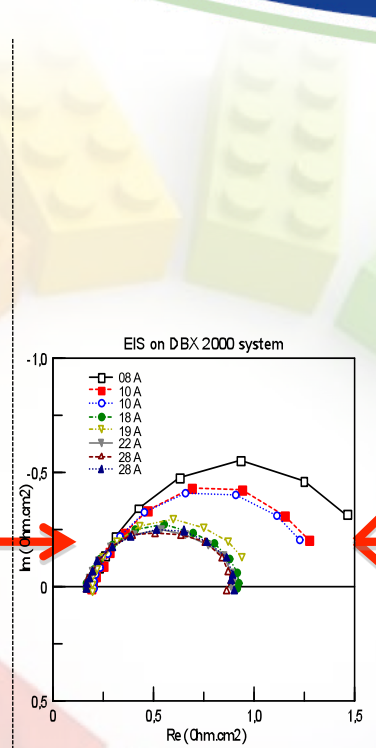
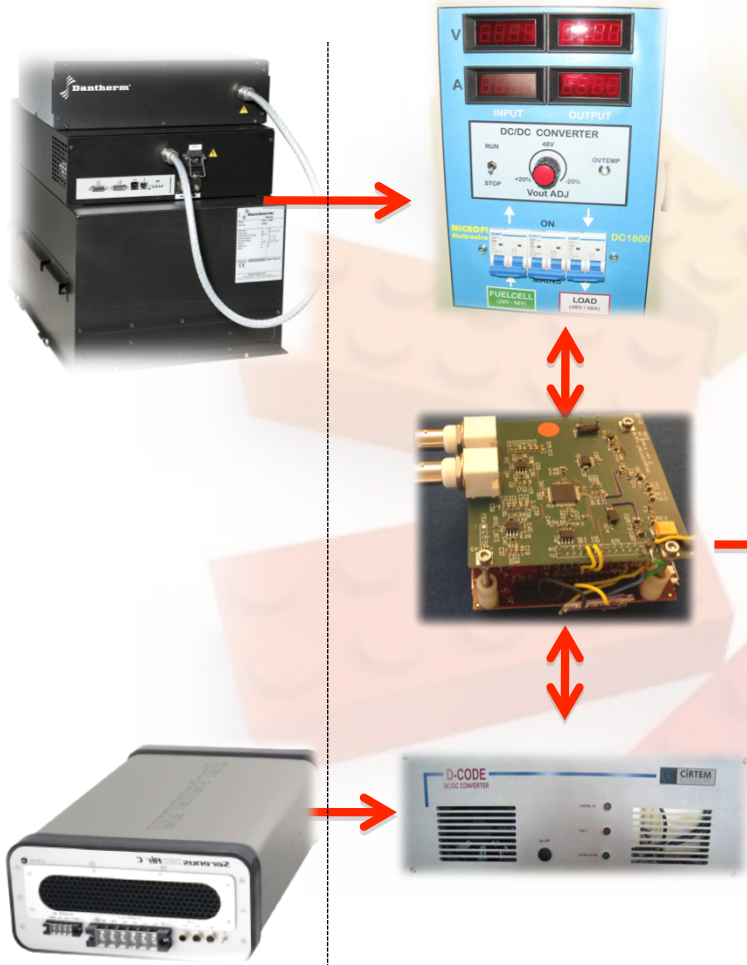


- Integrate the HW
- Implement the SW
- Use industrial standards



Project achievements 7/7

Results achieved at M18



Diagnosis

Alignment to MAIP/AIP 1/2

Application Area (SP1-JTI-FCH.2009.3.3)



Correlation with the Application Area: Stationary Power Generation & CHP
 Topic: Operation diagnostics and control for stationary power applications.

Issues addressed by the call's topic	D-CODE main objectives
<i>Effective control of stationary fuel cell stacks for optimum operation.</i>	On-board stack status detection to derive feedback information for control adaptation of LT and HT PEMFCs.
<i>Develop a better understanding of critical operating conditions and operating strategies and...</i>	On-line EIS , which carries the most meaningful information about the cell electrochemical processes.
<i>... establish a reliable management of interfaces with the application environment.</i>	New DC/DC hardware improves interface functions between power generators and load/grid.
<i>Development and utilisation of diagnostic techniques to reveal potential failures</i>	Implementation of diagnostic algorithms to detect and isolate faults from impedance spectrum. Analysis of EIS to diagnose incipient failures caused by either faults or cell degradation.
<i>... optimise run parameters and recovery methods in stacks and FC-units.</i>	Provide the control system with actual FC state information for control adaptation and recovery.

Alignment to MAIP/AIP 2/2

Project activities & results vs. MAIP/AIP



Topic Expected outcomes	D-CODE results and follow-up
<i>Novel diagnostics to identify potential failures, including in-operation diagnostic tools for cell/stack</i>	EIS is the most reliable diagnostic tool for FC, D-CODE transposes EIS-based diagnostic from lab scale to on-field applications . Faults and failures can be identified with a greater accuracy with respect to actual diagnostics.
<i>FC-unit level failure sensitivity matrix</i>	The availability of on-board EIS facilitates the FSM building . Monitoring of a large distributed power generation systems with EIS on-board may allow accumulating large data sets for FSM building.
<i>Improved prediction and avoidance of failure mechanisms</i>	Due to better accuracy and reliability EIS-based diagnosis can improve faults and failures detection .
<i>Development of strategies for recovery of cell and stack performance</i>	The empiricism of current controllers will be reduced through quantitative ad hoc feedback/adaptive control strategies with recovery features .
<i>Tools for improved field diagnostics and services</i>	Thanks to the high informative EIS content , EIS-based diagnostics can improve the effectiveness of FCS monitoring and serviceability through precise fault detection and identification.



Dissemination & Public Awareness 1/2

- A website has been set-up with the objective of sharing knowledge among partners and attracting third parties (www.d-code-jti.eu).
- **3 annual thematic workshops:**
 - 1st workshop held in Belfort (F) during the FC French Research Group Meeting (13-14/6/12):
8 invited speakers in two sessions; 3 speakers in the plenary session; Open to external attendants; Jointly organized with GENIUS project.
 - 2nd workshop will be held at the 5th FDFC in Karlsruhe (D), April 15-16, 2013.





Dissemination & Public Awareness 2/2

- **Papers** to conferences and international scientific journals will disseminate the project technological and scientific advancements:
 - 2 review papers are ready.
 - 3 papers are under preparation.

Training & education

- Three **PhD students** are currently active on the project topics, some **Master students** also contribute to the D-CODE activities.
- **Students' exchange** protocols are active: 2 UNISA's PhD students are on stage (9 months) at EIFER and UFC (1 co-tutored thesis, UFC-UNISA).

Standards

- Design, building and integration of converters, EIS board and FCS are performed by using industrial standards.

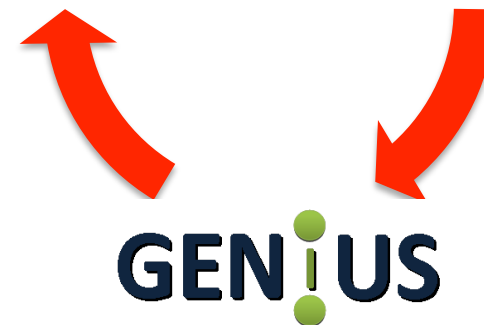
Cooperation and future perspectives

D-CODE strategy



Technology Transfer & Collaborations

- EIFER, UFC and UNISA are partners of GENIUS & DESIGN, methodologies and approaches for diagnosis are shared among them.
- Cooperation with Fraunhofer ISE (D) and Aalborg University (DK) are active for data exchange.
- External partners are Micropi (I) and Material Mates (I).



Future Programme should change the research paradigm

- Fundamental research should continue to find future solutions (e.g. materials).
- Strengthen the actual technologies improving FC-BoP interaction (e.g. control, diagnosis).
- Foster the implementation at industrial level of applied research methodologies, which can be borrowed from other areas (e.g. automotive, aeronautics).