



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

Start date: March 1, 2011

www.d-code.unisa.it

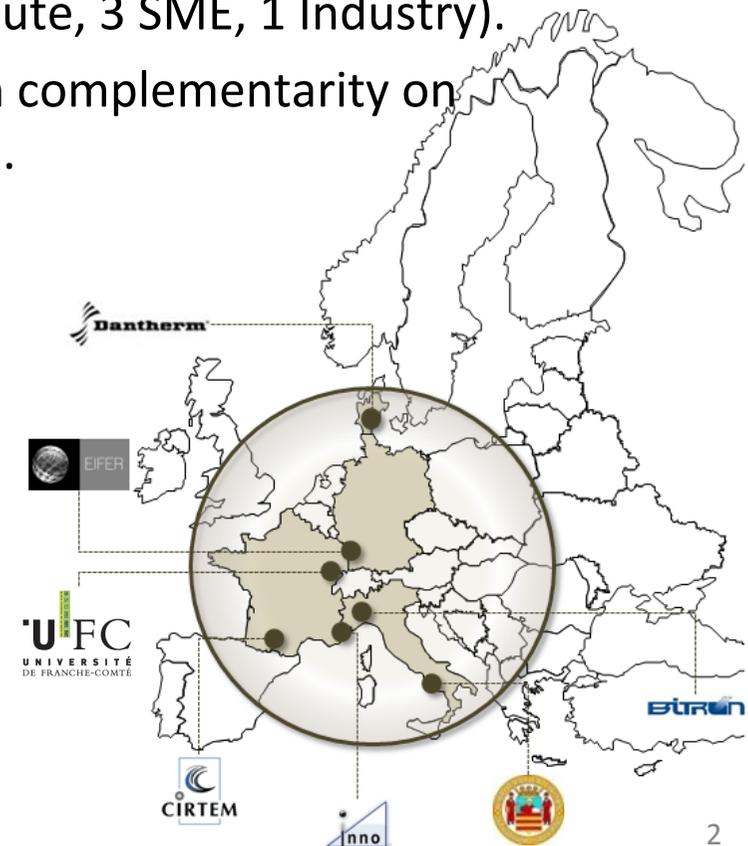
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- 36 months 01-03-2011 to 28-02-2014
- Budget 2.215 M€ - Funding 1.173 M€
- 7 partners from 4 countries representing a good mix of EU research and technology actors (2 Universities, 1 Research Institute, 3 SME, 1 Industry).
- Large experience in each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

goals & objectives

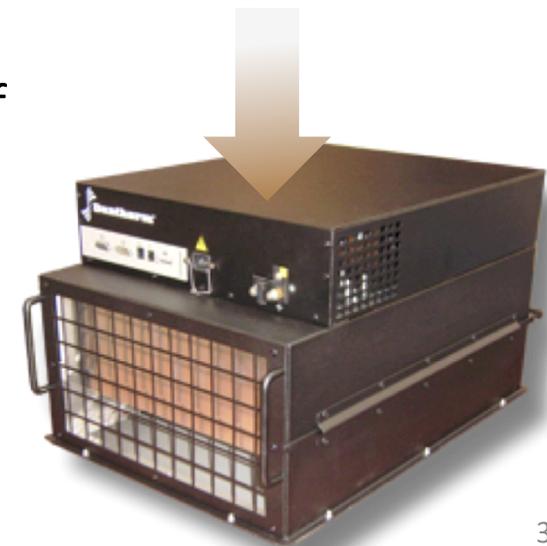
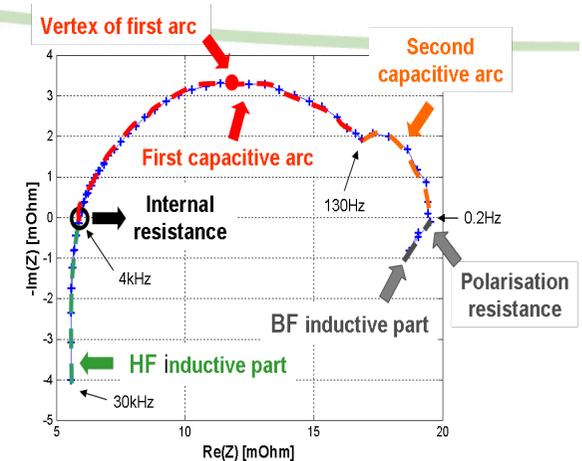


Main goals:

- Development of a **DC/DC converter 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.

Main objectives:

- Development of the power stage and control strategy of a **DC/DC converter to obtain the stack impedance spectrum on-board**.
- Derivation of a set of **indicators from the spectrum** to evaluate a **difference between the actual status and the nominal one**.



Project achievements 2/7

concepts & targets



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:

A realistic status of Stack & BoP can help 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.

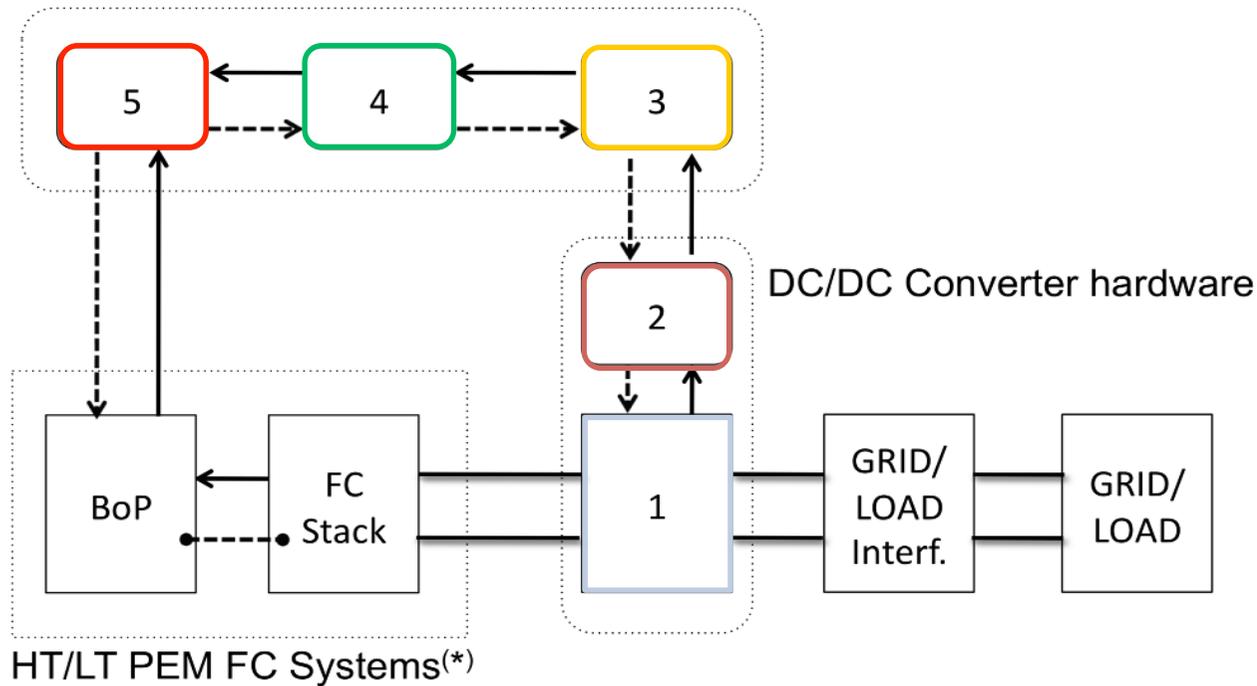


Project achievements 3/7

EIS-based on-board diagnosis HW



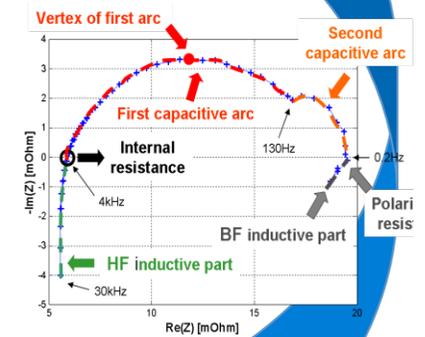
FCS's Electronic Control Unit



- ①— DC/DC power electronics with EIS functions
- ②— DC/DC converter controller for EIS
- ③— EIS command and signal evaluation
- ④— EIS-based diagnostic tool
- ⑤— Control & Diagnosis tool

(*) – For HT FCS the thermal system is not sketch

- Power connections
- > Commands actuations
- Measurements signals
- Fluids/Gases links



Stack/System
Fault Detection

Project achievements 4/7

accomplishments and progress towards SoA



Main innovations:

1. Develop EIS-based diagnostics for low and high temperature PEM fuel cells.
2. Use a single measure for meaningful FC state detection.
3. Control the on-board DC/DC converter to generate EIS signal stimulus.
4. Embed the EIS-based diagnostic tool in the electronic control unit (ECU).
5. Derive FC degradation/diagnostic information while the system is running.
6. Design and build an improved DC/DC converter.

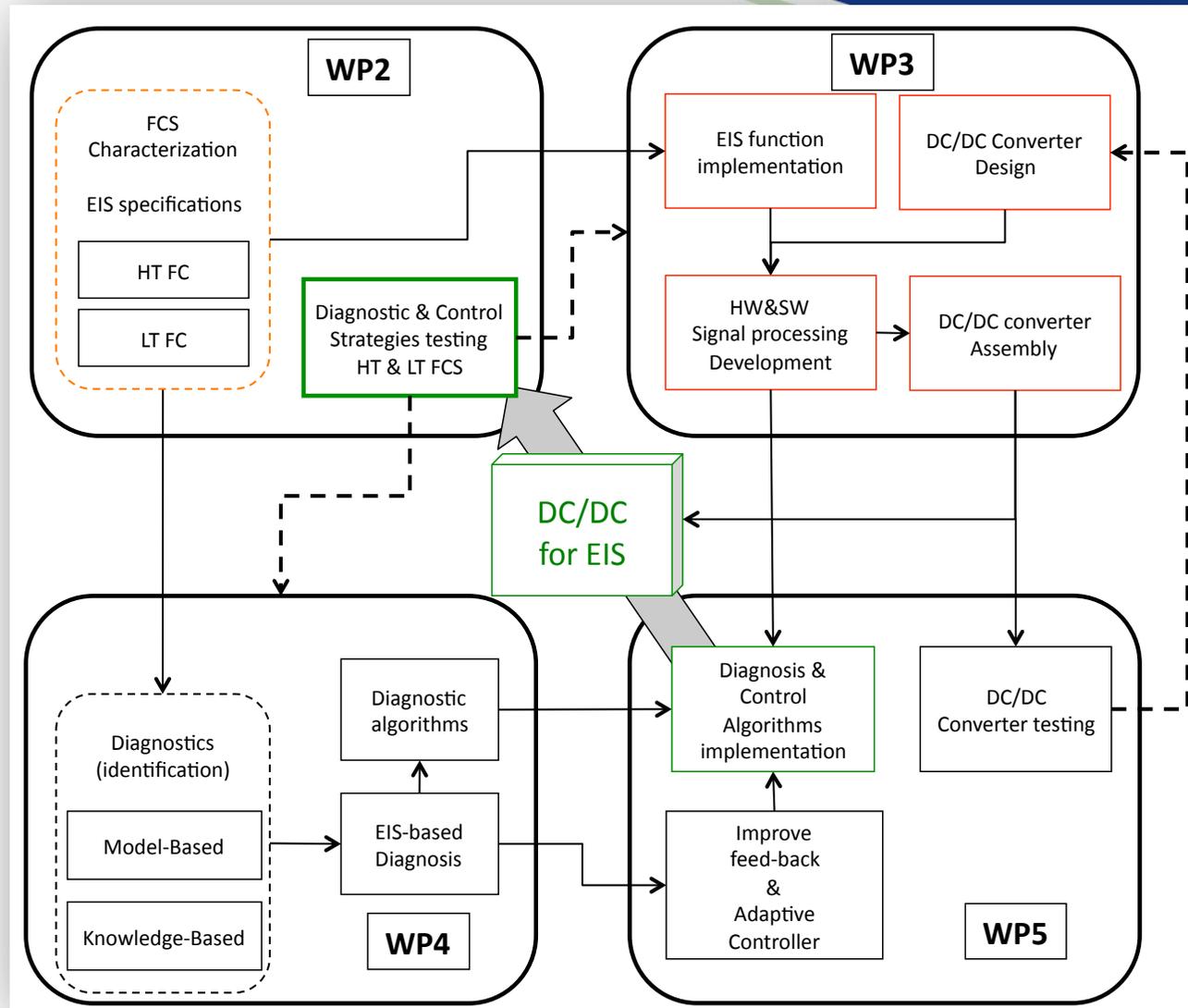
Boost operational capabilities of LT and HT PEMFC fostering their deployment

Key concepts suitable for all FC technologies (“universal”)

The new converter functions can enhance the interfacing functions between power generators and grid/load,

Project achievements 5/7

D-CODE WORKFLOW



Main outcomes:

2 FCS (LT/HT) applications, low temperature (backup) and high temperature (μ CHP).

2 DC/DC converters, low and high voltage (LV/HV).

4 combinations LV/HV-LT/HT.

Degradation and fault diagnosis detection strategies.

2 approaches for diagnosis, Model & Knowledge-based.

RLC model parameters, on-board fast identification.

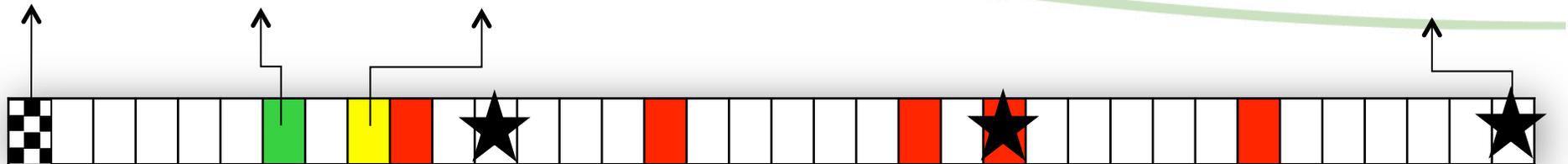
Project achievements 6/7

strategic milestones



Kick-Off Meeting M7 Review Day
 1/3/11 22/9/11 22/11/11

28/2/14



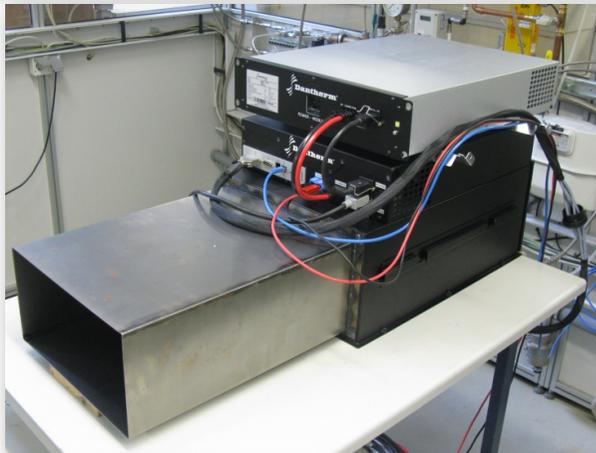
Date	Milestones
M10	Computational structure for FCS monitoring
M16	LT PEMFCS monitoring algorithms ready for fault detection use
M22	Working LT FCS with EIS diagnostics and control SW ready for testing
M24	DC/DC converter prototype with EIS functions incorporated, start of testing
M24	Monitoring algorithms for HT PEMFCS
M30	Working HT FCS with EIS diagnostics and control, ready for testing

Project achievements 7/7

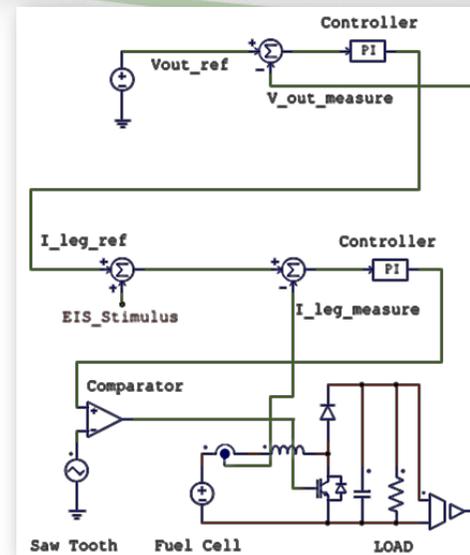
some accomplishments @ M7 (22/09/2011)



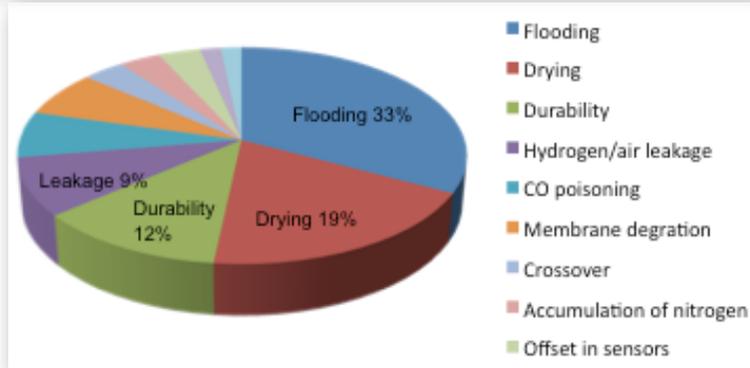
WP2 – Low Temperature PEM FCS from Dantherm customized at EIFER labs for testing.



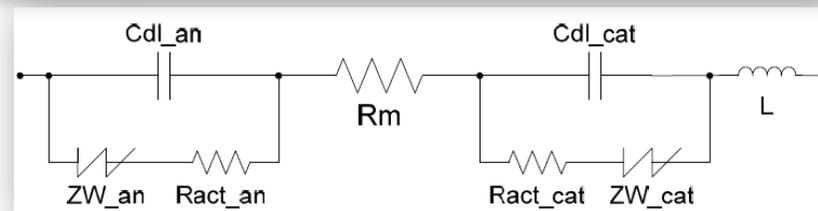
WP3 – first EIS controller designed.



WP4 – Recognition of the common faults and degradation processes; bibliographic search.



WP4 – Setting of the reference RLC model and parameters identification via EIS data.



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
<p><i>Novel diagnostics</i> to identify potential failures, including in-operation diagnostic tools for cell/stack</p>	<p>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.</p>
<p>FC-unit level failure sensitivity matrix</p>	<p>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.</p>
<p>Improved prediction and avoidance of failure mechanisms</p>	<p>Due to better accuracy and reliability EIS-based diagnosis can improve faults and failures detection.</p>
<p>Development of strategies for recovery of cell and stack performance</p>	<p>The empiricism of current controllers will be reduced through quantitative ad hoc feedback/adaptive control strategies with recovery features.</p>
<p>Tools for improved field diagnostics and services</p>	<p>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.</p>



Dissemination & Public Awareness

- A website has been set-up with the objective of sharing knowledge among partners and attracting third parties (www.d-code.unisa.it).
- **Annual thematic workshops** will be organized, the first event will be held in Belfort (F) during the FC French Research Group Meeting (June 2012).
- **Papers** to conferences and international scientific journals will disseminate the project technological and scientific advancements.

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 under definition (PhD co-tutored thesis).

Standards

- Industrial standards are considered for all project activities. Design and manufacturing activities are performed by industrial partners that have prominent roles in their market areas.



Technology Transfer / Collaborations

- EIFER, UFC and UNISA are partners of other two FCH-JU projects (GENIUS and DESIGN) dealing with diagnosis for SOFC. Methodologies and approaches for diagnosis are shared among these projects.
- Some partners already interacts since several years in the framework of other National/ European projects (PRIN-I, Diapason II-F, SMART-D, Erasmus).
- The project enhances the interactions among FCS manufactures and components suppliers through the exploitation of advanced scientific and technical concepts (power electronic devices, diagnosis, modelling).

