

REliable Advanced Diagnostics and Control Tools for Increased Lifetime of Solid Oxide Cell Technology

EU project REACTT-Advanced Field Diagnostics of SOEC & rSOC

Dani Juričić Institute Jožef Stefan dani.juricic@ijs.si WORKSHOP FROM BASIC TO APPLIED RESEARCH TOWARD DURABLE AND RELIABLE FUEL CELLS 5 July 2022 – Lucerne (CH)



WORKSHOP "FROM BASIC TO APPLIED RESEARCH TOWARD DURABLE AND RELIABLE FUEL CELLS", 5 July 2022 – Lucerne (CH)



Project overview



	Partners	Short name	Country	Call identifier	H2020-ITI-FCH-2020-1
1	Institute Jožef Stefan	IJS	Slovenia	Торіс	FCH-02-3-2020
	(Coordinator)				Diagnostics and Control of SOE
2	Commissariat à l'énergie atomique et	CEA	France	Project number	101007175
	aux énergies alternatives			Start	1-JAN-2021
3	Università degli Studi di Salerno	UNISA	Italy	End	31-DEC-2023
	(Coordinator)		,	Duration	36 months
4	Ecole Polytechnique Fédérale de	EPFL	Switzerland	Budget	2.712.322 €
	Lausanne				Associated with document Ref. Ares(2
5	Bitron S.p.A.	BITRON	Italy		
6	SOLIDpower S.p.A.	SP	Italy		
7	Teknologian tutkimuskeskus VTT Oy	VTT	Finland	Hes.so?	PROFESSION
8	AVL LIST GMBH	AVL	Austria	C23	AVL %
9	AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE,	ENEA	Italy		Jožef Stofan
10	Haute Ecole Spécialisée de Suisse occidentale	HES-SO	Switzerland		





Co-funded by the European Union



Objectives

- **Objective 1:** Improved durability, reliability and maintainability of SOE and rSOC stacks by developing innovative algorithms for diagnostics and prognostics of their remaining useful life.
- **Objective 2**: Advanced control strategy with self-optimizing and fault-tolerant features
- **Objective 3: Hardware module** for implementation of the monitoring, diagnostics, prognostics and control
- **Objective 4**: Characterization of stacks and systems in SOE and rSOC nominal and faulty conditions and validation of the product prototype







Project structure

Project managemet (WP1)



Dissemination, communication, standardization and exploitation (WP7)



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Ties with other EU projects



Project	Relevance
INSIGHT	EIS and PRBS measurements on SOFC short stack and full-stack, diagnostic algorithms, prognostic algorithms, mitigation strategies, HW modifications for on-board measurements, SW implementation.
DIAMOND	stack and system diagnostic algorithms, system control algorithm, on- board implementation.
AD ASTRA	Accelerated stress testing protocols for SOFC/SOEC cells and stacks, degradation models, stack diagnostics.
D-CODE	PEMFC - EIS board, power electronics, monitoring and diagnostic algorithms
HEALTH- CODE	PEMFC - EIS-based monitoring and diagnostics, power electronics, advanced EIS board, fault testing and experiments
RUBY	EIS and PRBS measurements on PEMFC and SOFC full stacks and systems, diagnostics, prognostics, mitigations strategies, control, HW design, SW implementation, 1 year testing on field, SOFC system certification.





Impact



	Impact	KPIs	Unit	Target
1	Increase of the overall manufacturing cost due to the inclusion of the MDPC tool	Manufacturing cost of the MDPC HW	€	Less than 3%
		Manufacturing cost of the excitation module		
		SW cost		
		Cost of integration		
2	Improve stack performance and system availability	Production loss	%/1000h	1.2
2		System availability	%	98
3	Improve system efficiency	Electricity consumption @rated capacity	kWh/kg	39
4	Improve SOEC system productivity	Electricity consumption @rated capacity	kWh/kg	39
		Operation and maintenance cost	€/(kg/d)/year %	120 Decrease by 10%
		Cost of hydrogen production	€/kg	na.
		ТСО	%	-15%
5	Improve durability	Stack estimated lifetime	years	+5%



SP

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Experiments on stacks



Segmented cell Supporting full cells



CEA test bench





Stackbox from SP

70 cells
91V DC output voltage

Short stack from

6 cells

55V DC

(thermoneutral)



Segmented cell test in a 4-cells stack (EPFL)

Column



Experiments (short stacks)



OCV as a function of H2O/H2 and T as expected
 Improvement of performances with T and H2O+H2 flowrate



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Initial electrochemical characterization results: EIS in SOFC mode at 750 °C (DC: 0.5 A & amp.: 100mA)







Embedded HW design



- AFE: Analog Front End for current and voltage acquisition of rSOC/SOE
- New Ethernet Bridge custom for PC, Raspberry, AFE, RTO,EM)
- DC DC Converter (24V to 5V)
- Raspberry



The first prototype of the REACTT MDPC board



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Clean Hydrogen Partnership Excitation module

Cycle-by-cycle current sense

Output Current Controller

Output current sense

Stack

SOE

Capacitance as low as possible

DC current setpoint

Excitation waveform



Synchronisation

with Bitron board



Solid-state

Switches

Output Filter

Switching

Controller

Peak current mode

controlla

Synchronous switching

The concept: serial connection of the main power supply and the excitation module wide bandwidth operates with standard power suplies no loss in efficency extra HW cost extra space /weight

Reactt HAT

Co-funded by the European Union

The goal

AC

Rectifier

or DC

Power

Source

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Current

Ø Output

Fault

0.98

0.96 0.94 0.92

0.9

0.88

detectio

FAULT ISOLATION

FAULT

FAULT TREE ANALYSIS

Fault

Event





Predicted ECN

parameters

evaluated ECN

parameters

stem varia

Tin

Training

GP regression

model

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Predicted

Nyquist

curves

Change

detection





TOP LEVEL

BASIC LEVEL

INTERMEDIATE LEVEL



FEATURES NOMINAL AND

FAULTY BEHAVIOUR MAPPING



 Q_2

 Q_3

 Q_1



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Physically based modelling of degradation phenomena





Clean Hydrogen Partnership reac(tt)



Clean Hydrogen Control system hyerarchy











- Experimental campaign on the 2 short stacks and a segmented cell stack performed
- MDPC first prototype board available
- Excitation module: the first version (without communication) completed and tested
- Diagnostic algorithms: EIS and model-based algorithms under validation on the data from experimental campaigns
- Prognostic algorithms: the concept is set up
- Degradation modelling: Microstructural and electrochemical modelling of Ni mobility
- Control design: first versions of the tracking controllers and real-time optimizing control algorithms validated on the simulator





: Dissemination and communication



A Dissemination and Communication Action Plan (DCAP) has been delivered. Development of REACTT identity: project logo, templates for

Development of REACTT identity: project logo, templates for deliverables and presentations, and project flyer **finalized!** (D7.1)



Development of project website: https://www.reactt-project.eu/

- Project description, promotional and educational material, news, links to related projects;
- Internal pages (knowledge exchange, documents download).









Thank you!

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This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking (now Clean Hydrogen Partnership) under Grant Agreement No 101007175. This Joint Undertaking receives support from the European Union's Horizon 2020 Research and Innovation programme, Hydrogen Europe and Hydrogen Europe Research.



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