Project RUBY

Robust and reliable general management tool for performance and durability improvement of fuel cell stationary units

MDPC PLATFORM FOR ON-FIELD EIS OF FUEL CELLS AND ELECTROLYSERS

ENNIO ANDREA ADINOLFI, GIOVANNI SPAGNUOLO (UNISA)

GIUSEPPE CATONA, CARLO TANZI (BITRON)

Agenda

- Context and Framework
- Objectives and Challenges
- From Lab to on-field application
- EIS injection strategies
  - Switching converter-based actuation
  - EIS perturbation add-on
- Diagnostic tool evolution
- Conclusions

Funded by the EU Fuel Cell and Hydrogen 2 Joint Undertaking (now Clean Hydrogen Partnership) – H2020 Programme Grant Agreement Number 875047

MDPC platform for on-field EIS of fuel cells and electrolysers

CONTEXT AND FRAMEWORK

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EU projects pathway

DECODE

EIS HEALTH CODE

insight

RUBY

reac tt

2011

2015

2017

2020
2021

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MDPC platform for on-field EIS of fuel cells and electrolysers

OBJECTIVES AND CHALLENGES

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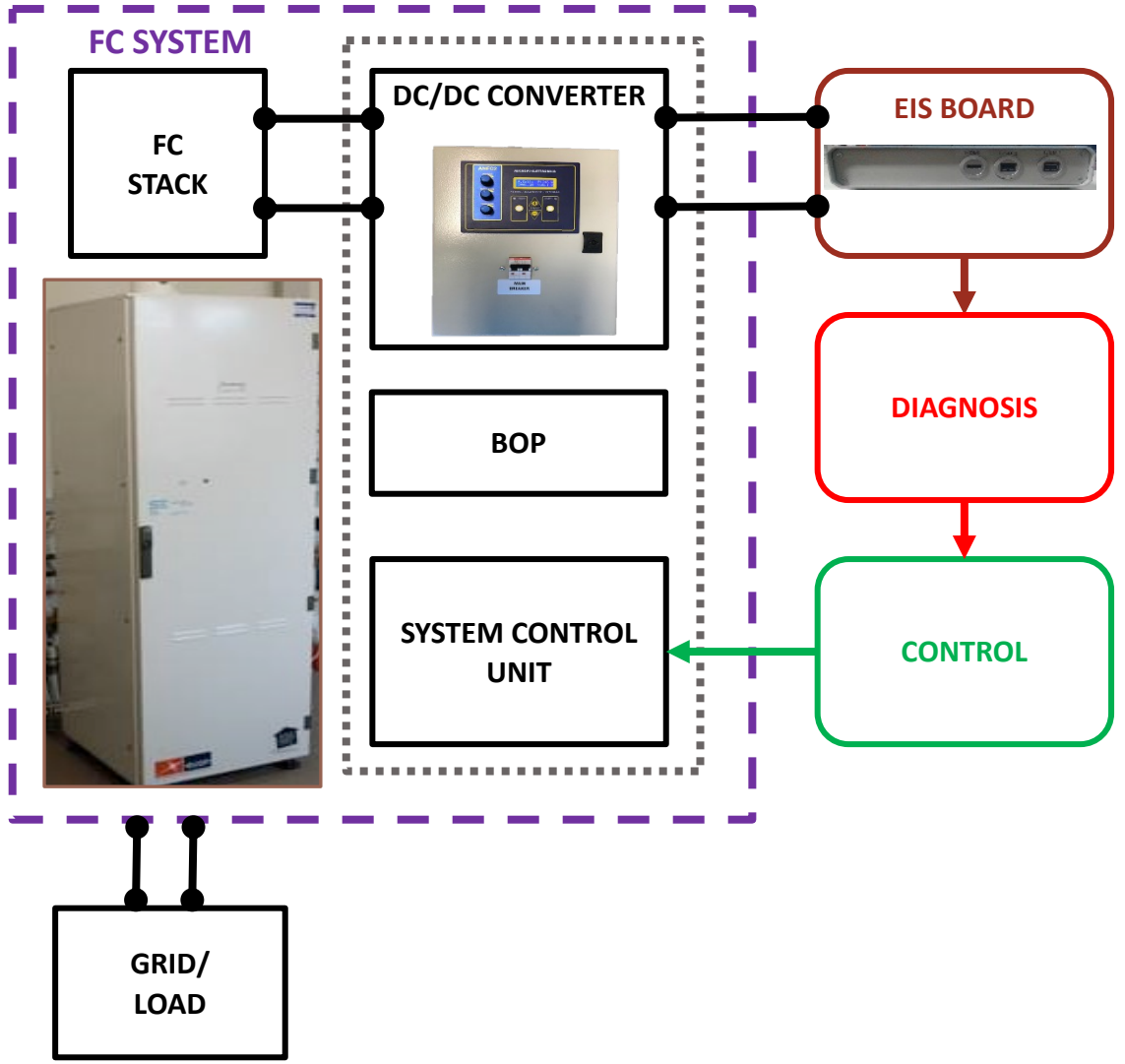
Objectives and Challenges

- Different hardware
- Significant or minor changes to existing hardware
- EIS-oriented stimuli injection is the major issue
- Measurements accuracy
- Market/industries sensibility



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MDPC platform for on-field eis of fuel cells and electrolysers

FROM LAB TO ON-FIELD APPLICATION

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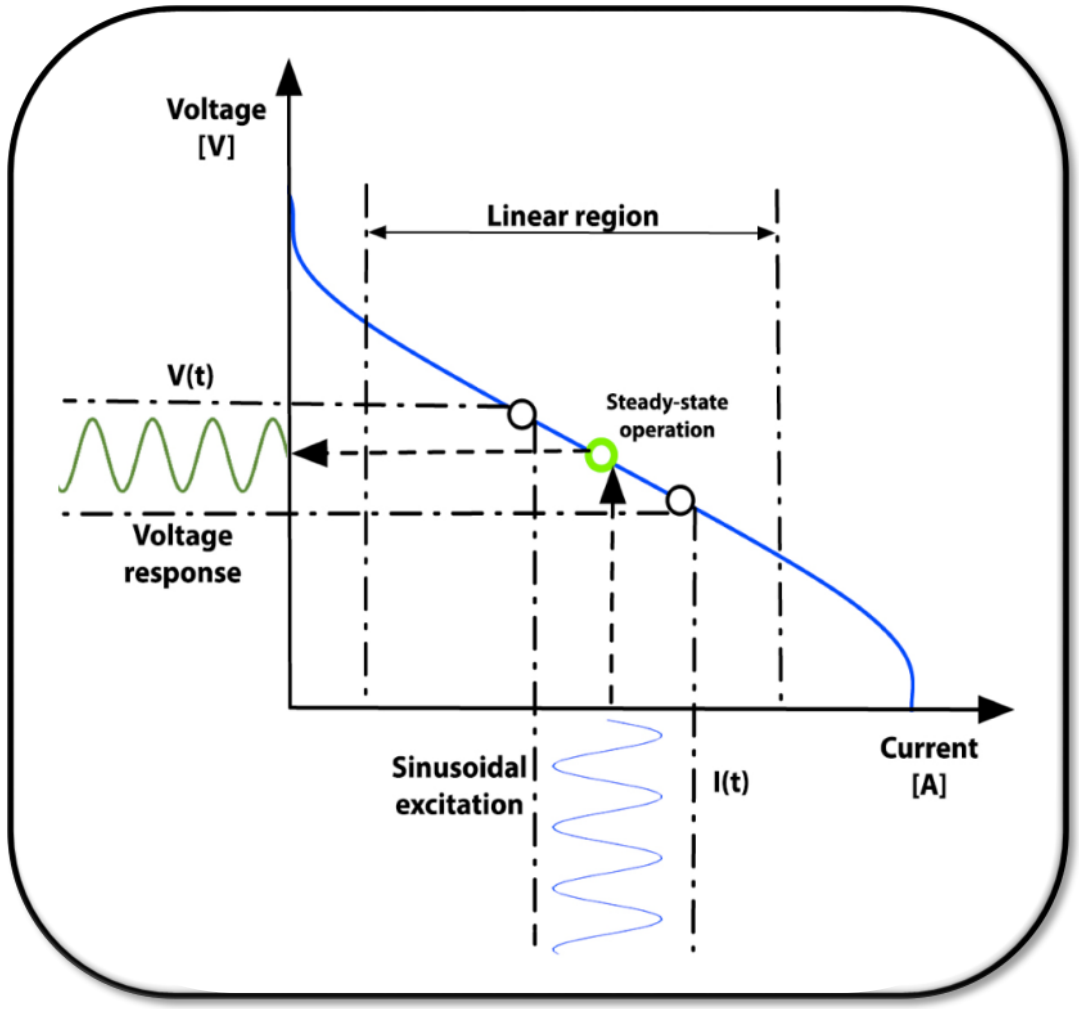
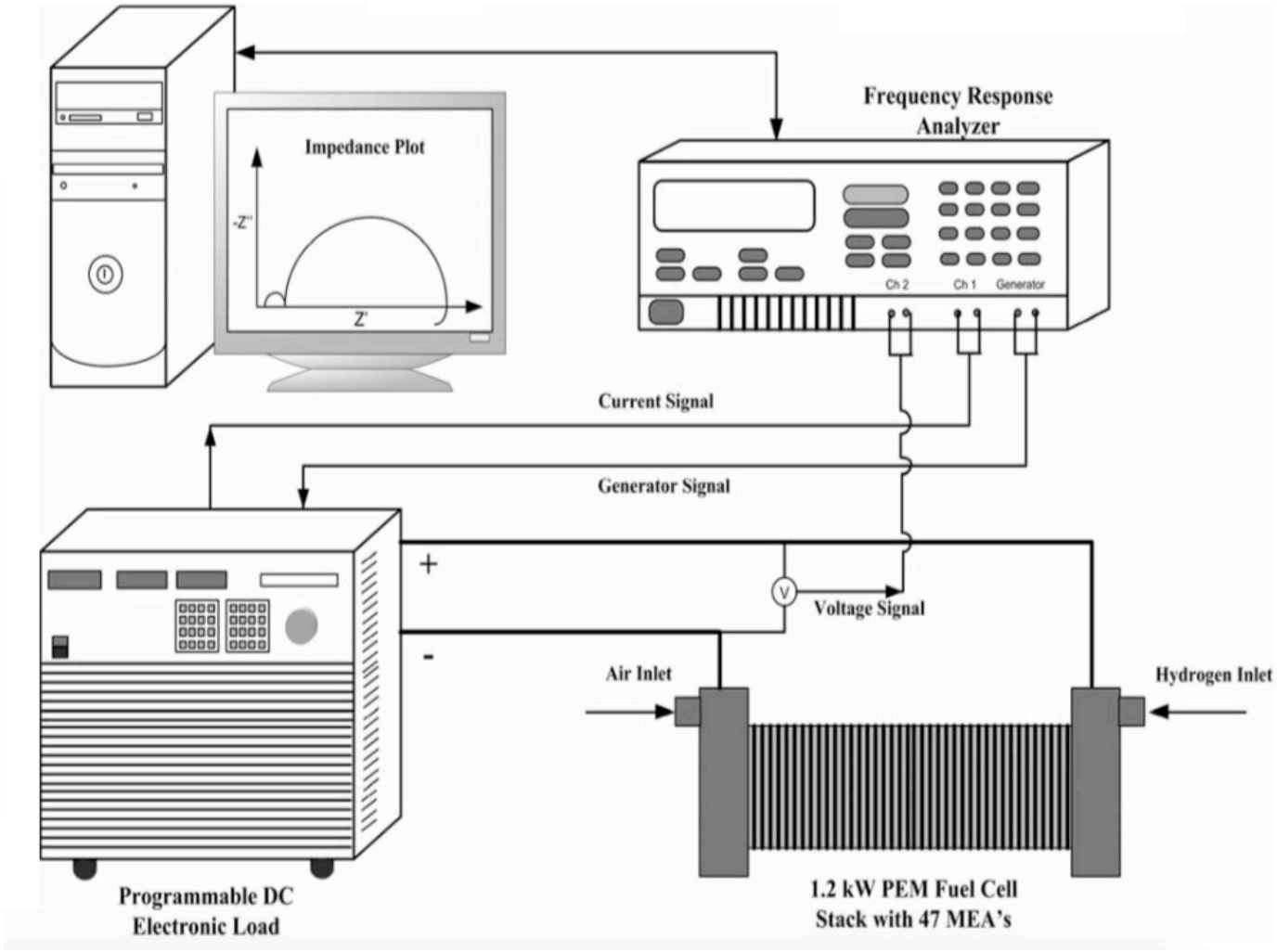
EIS principle and Lab implementation





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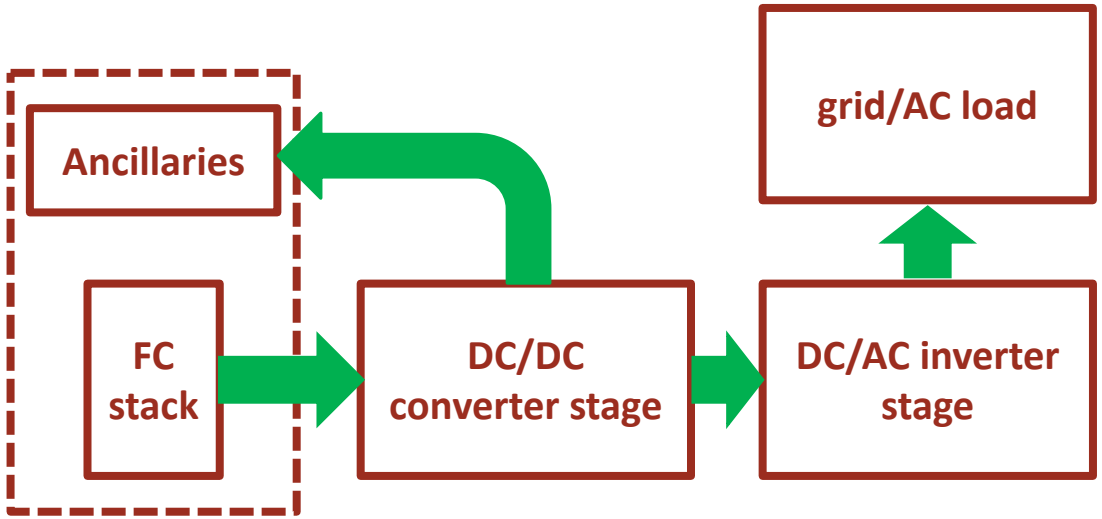
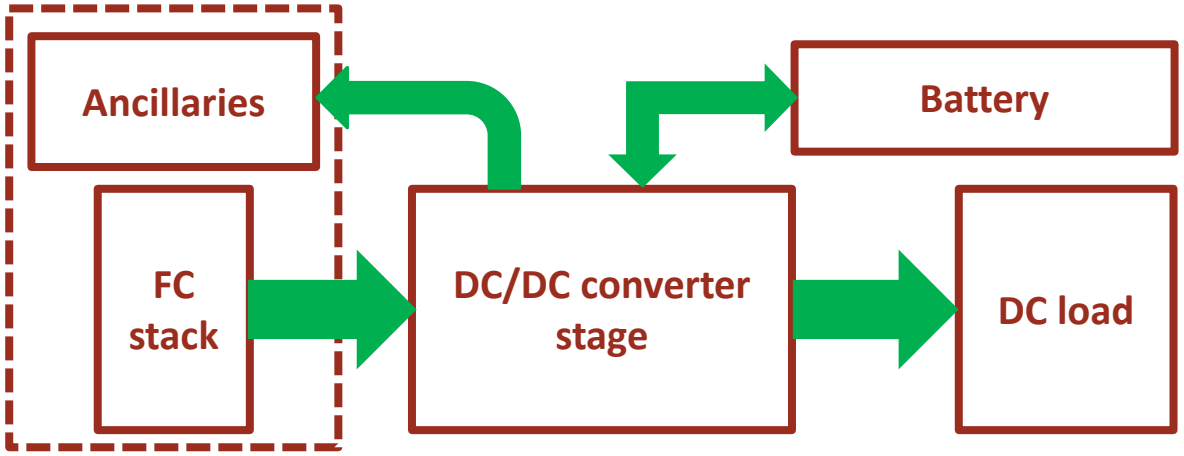
On-field application





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MDPC platform for on-field eis of fuel cells and electrolysers

EIS INJECTION STRATEGIES

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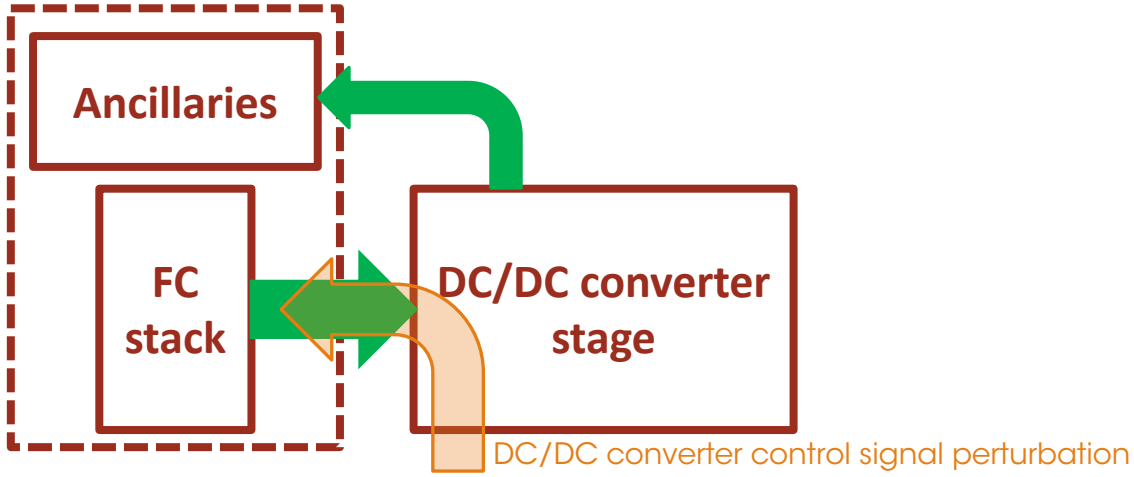
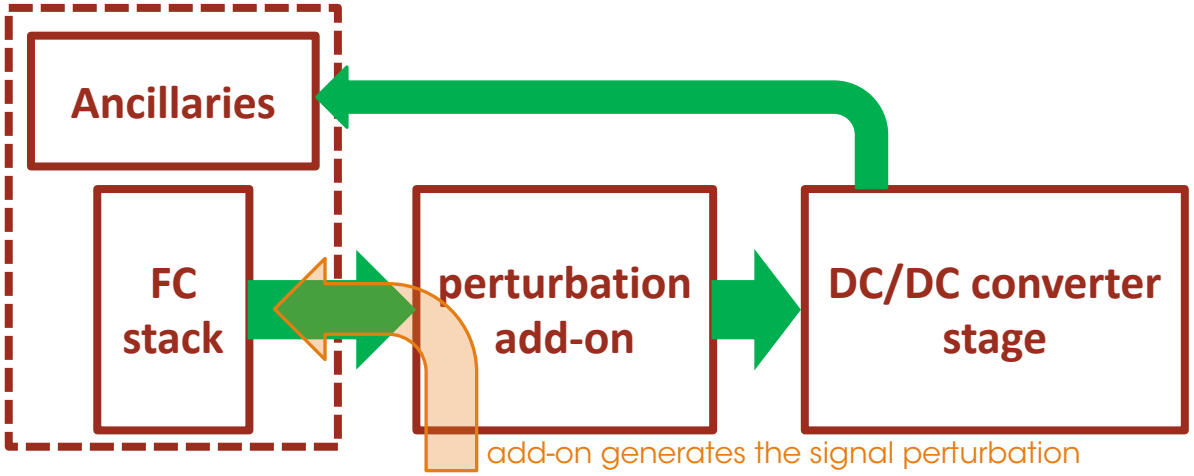
EIS perturbation injection strategies

Switching converter-based actuation



EIS perturbation injection through add-on hardware



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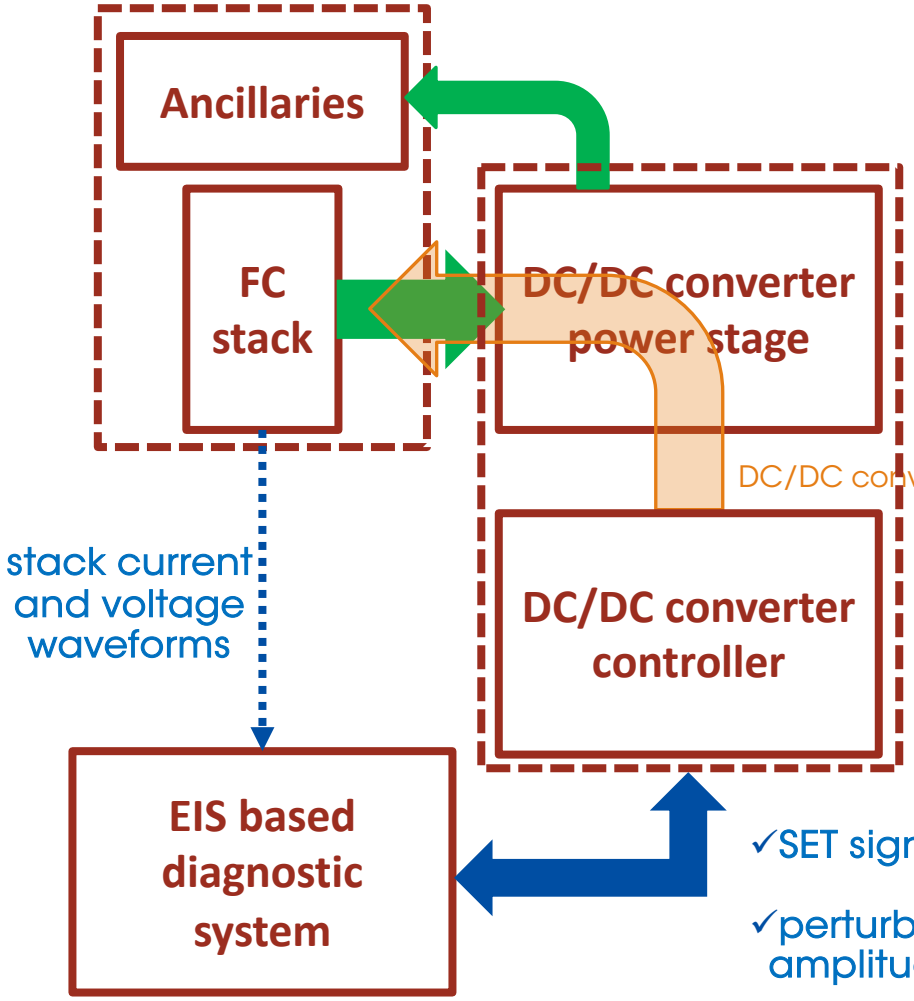
Switching converter-based actuation



Advantages

- limited or no impact on the **conversion efficiency**
- **compactness**
- easy **integration** in the system as a whole

- ✓SET signal to start perturbing action
- ✓perturbation signal frequency, amplitude, duration,…
- ✓GET status of the DC/DC converter

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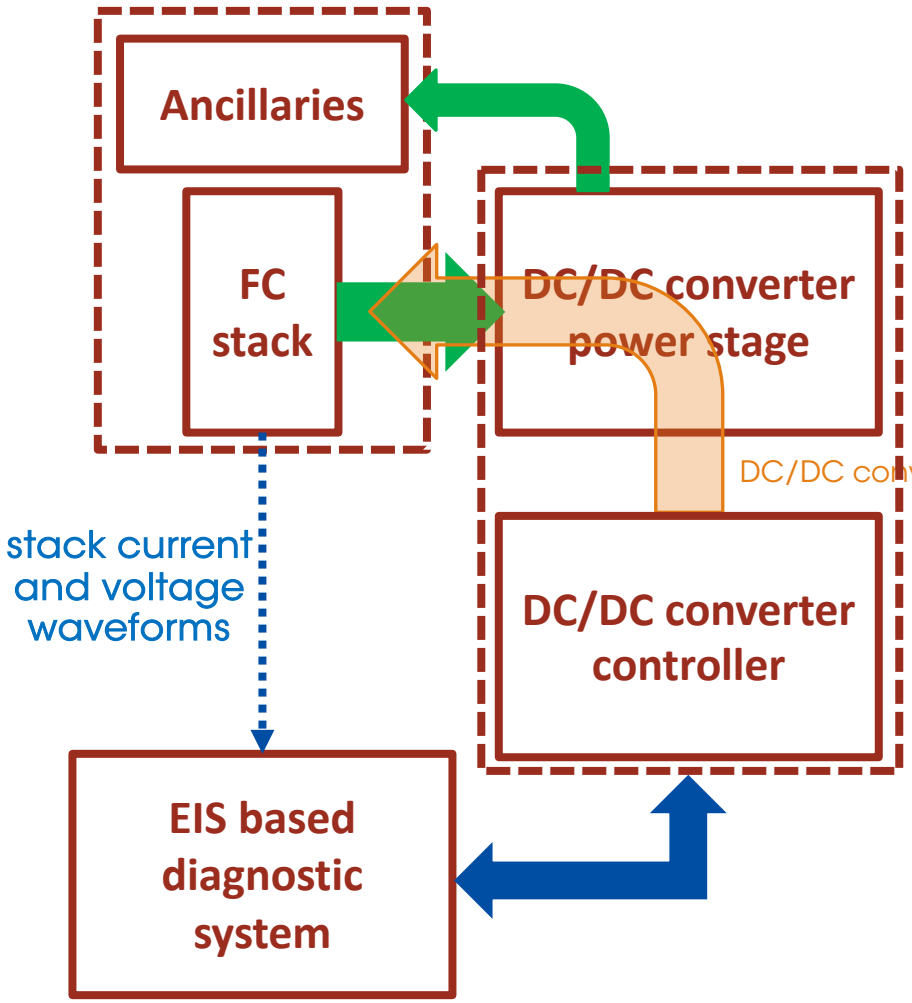
Switching converter-based actuation



Challenging issues & drawbacks

- Ensure **communication**, through a suitable protocol, with the DC/DC converter controller/processor
- DC/DC converter **control-to-input transfer function** with a suitable bandwidth

Control-to-input transfer function depends on:

- converter input filter
- switching frequency
- converter control loops

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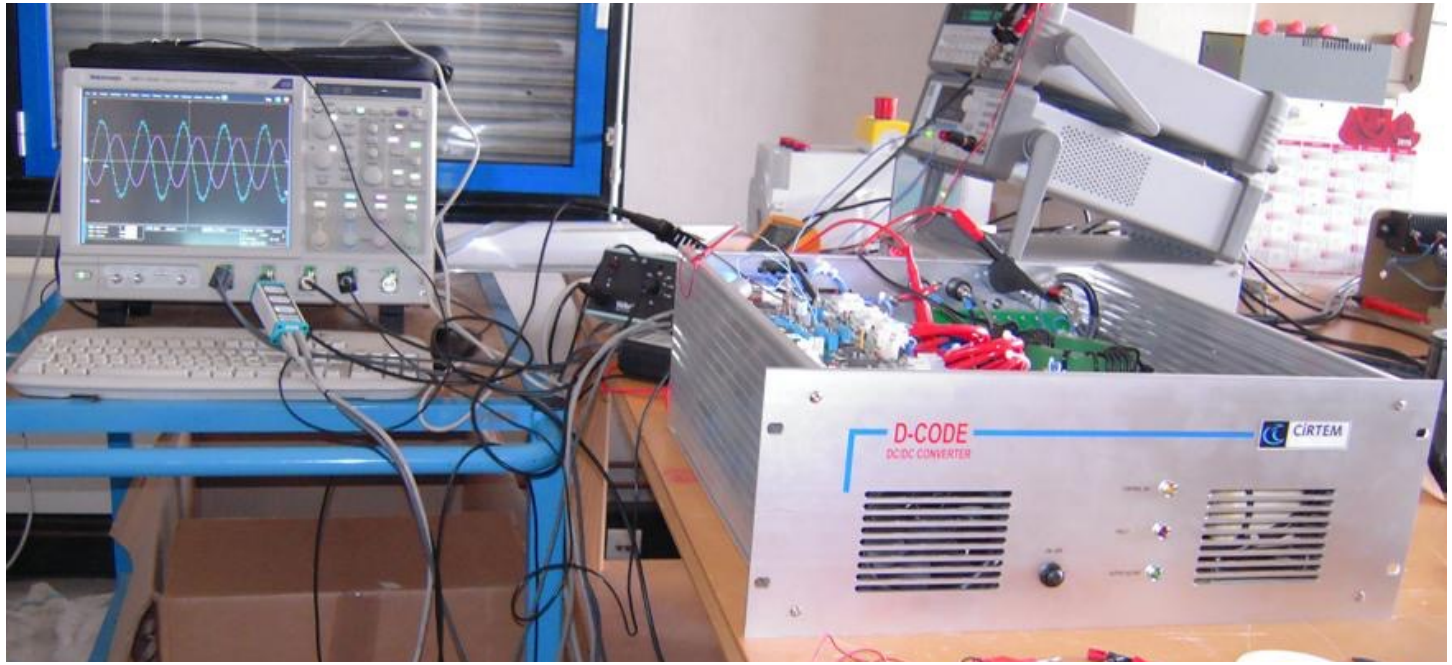
Switching converter-based actuation

Designed, engineered and developed converters



Boost topology (15-60V up to **380V**)
Three interleaved legs (lower input ripple)
Hard switching: 9-18 kHz (preferred 18 kHz)
Current reversible topology: EIS analysis when the DC current of the FC is zero
600 V IGBTs with SiC diodes (high efficiency)

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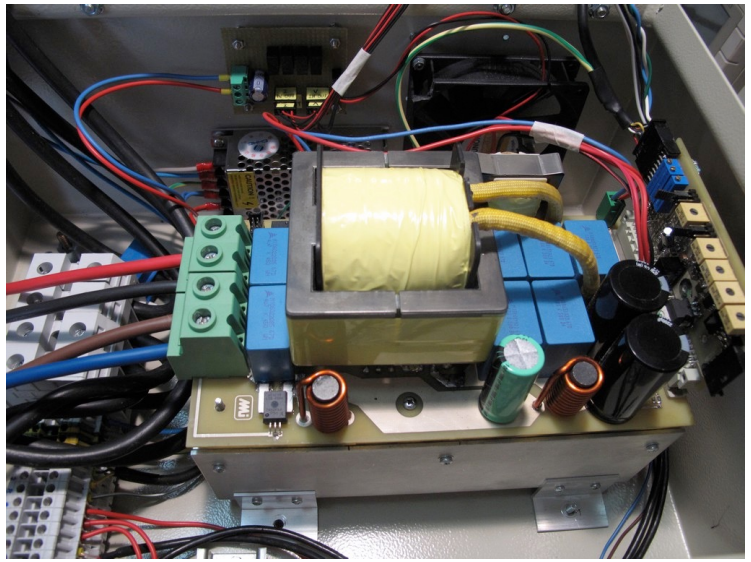
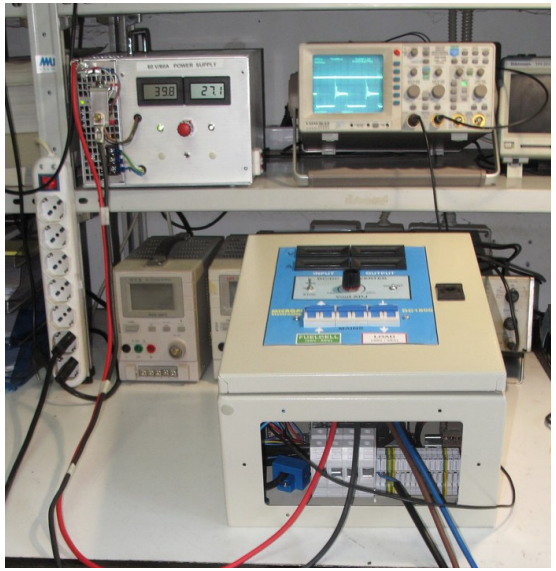
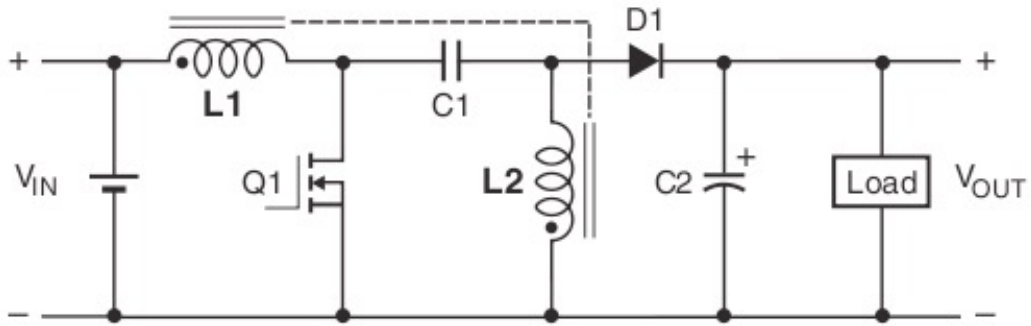
Switching converter-based actuation

Designed, engineered and developed converters







Stack voltage range [15 V, 60 V]
Output DC voltage **48 V**
Rated power 1.8 kW
Non inverting step-up/step-down DC/DC converter: coupled inductors SEPIC (Single Ended Primary Inductor Converter) topology.

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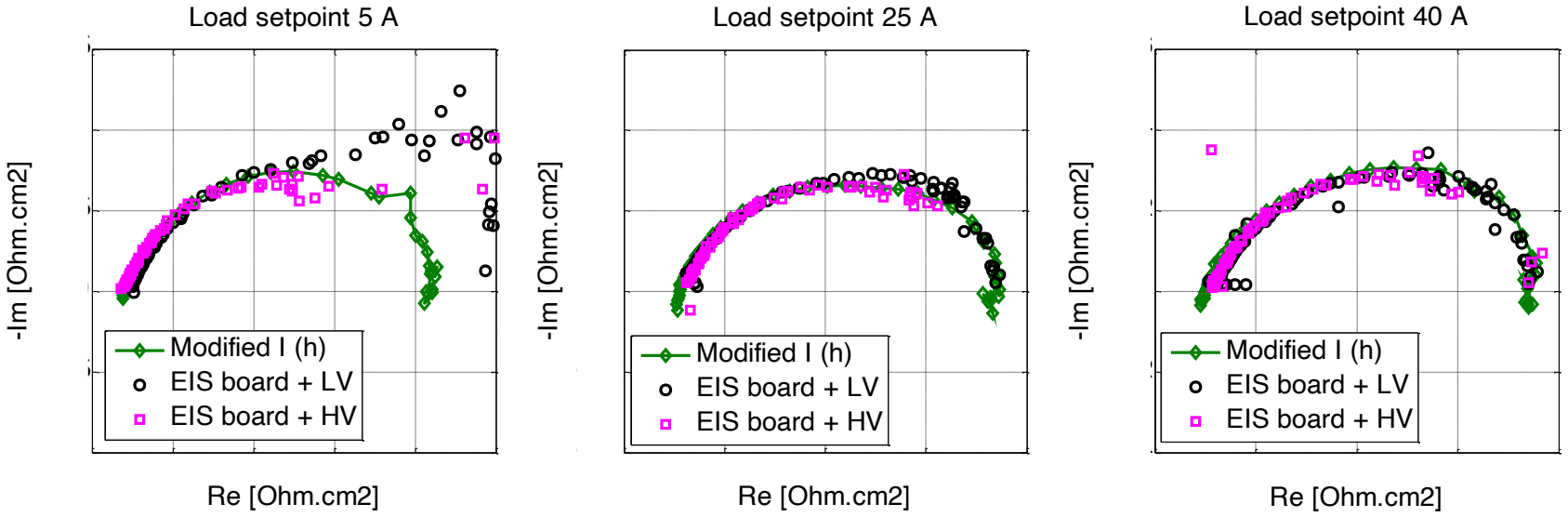
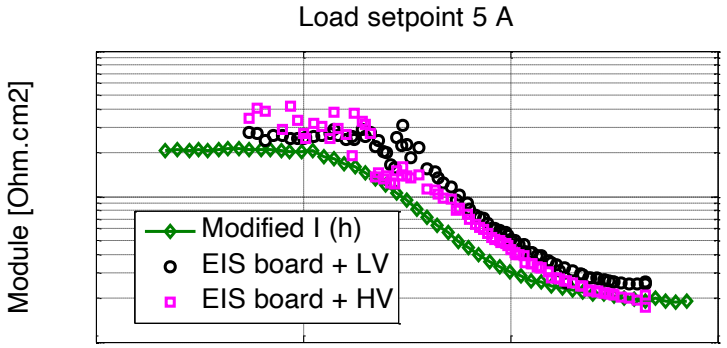
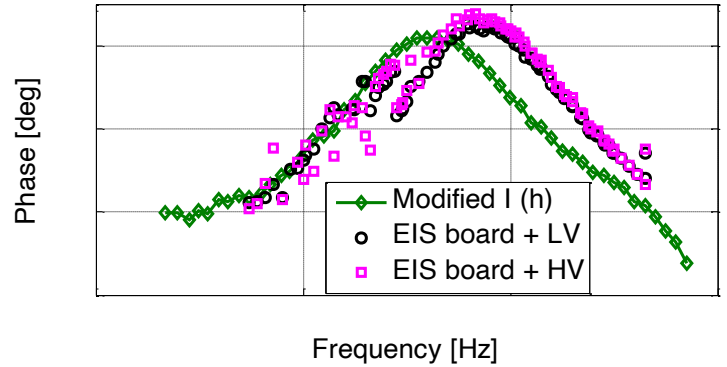
Experimental data

Designed, engineered and developed converters





Comparison among data acquired through **laboratory equipments**, **high voltage** DC/DC converter and **low voltage** DC/DC converter.



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Switching converter-based actuation

Designed, engineered and developed converters

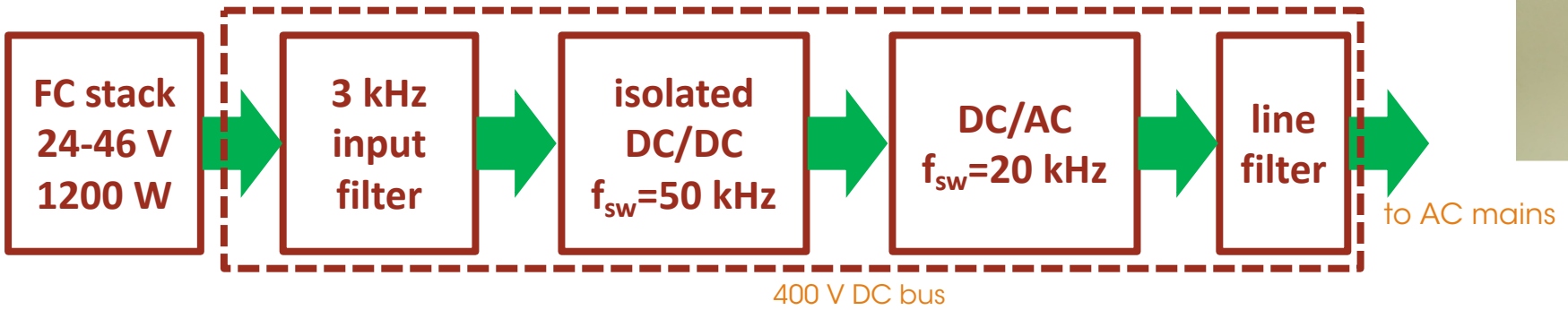
230 V **inverter**

DC Input current range: 0-45A (step 1 A)

Rated power 1.2 kW

Stimulus frequency range 0.05Hz to 2000Hz

Stimulus amplitude range 0-10% of the DC current



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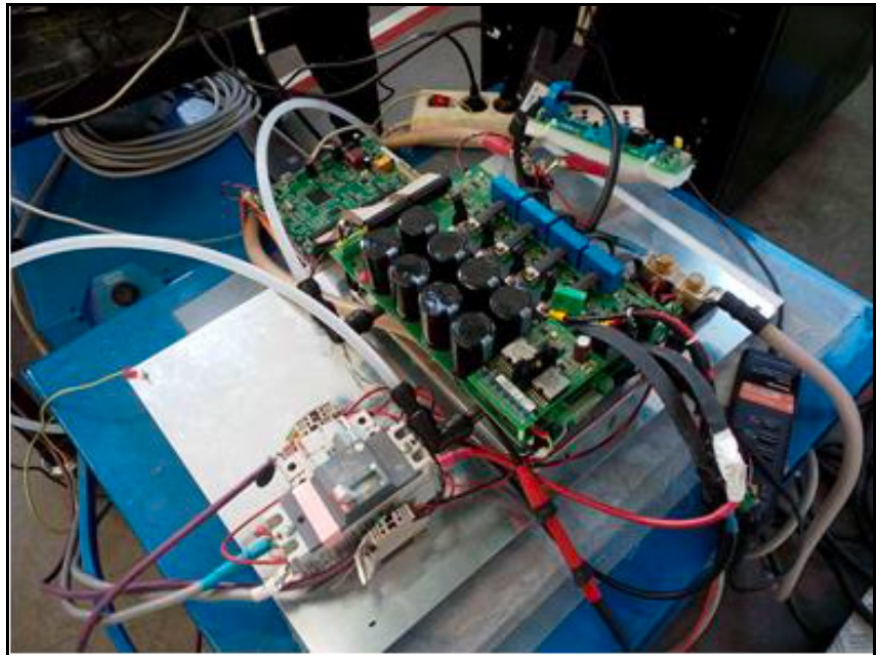
Switching converter-based actuation



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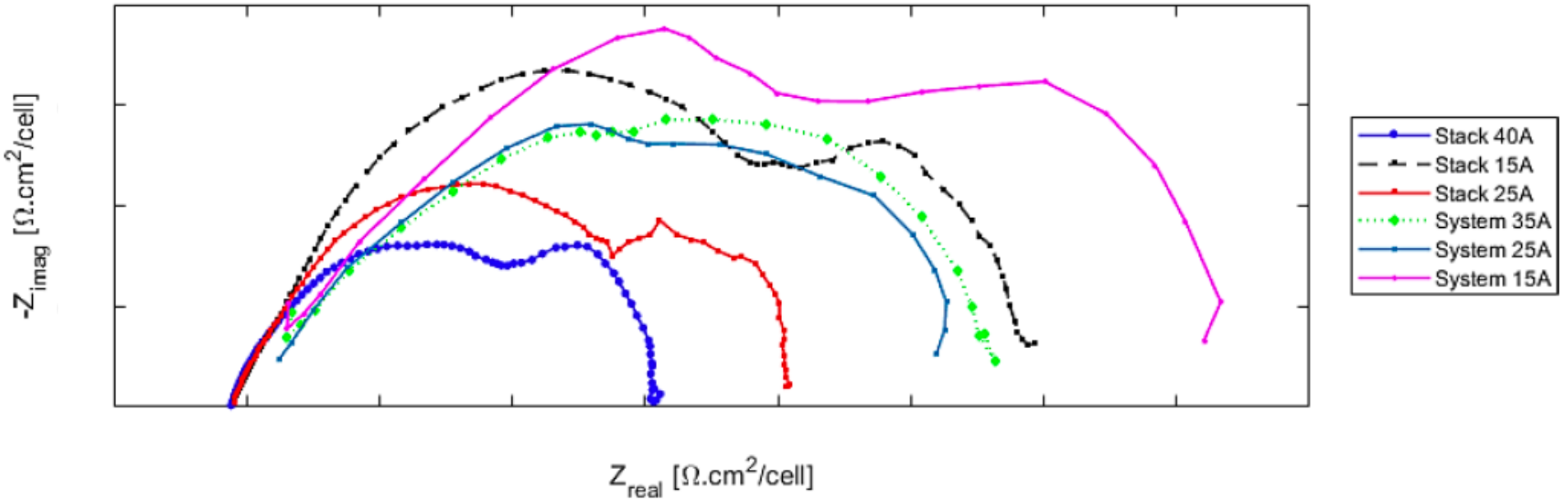
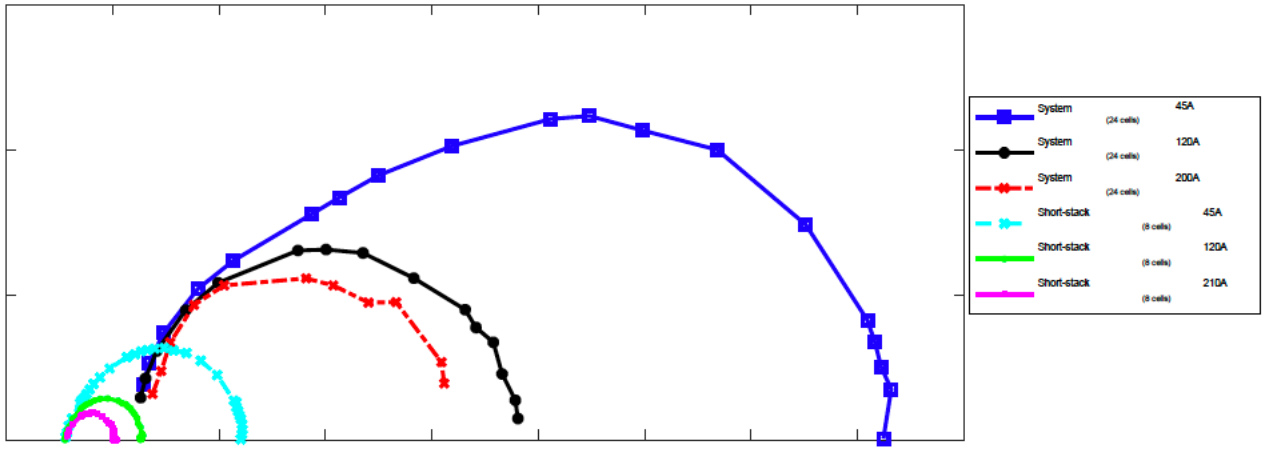
Experimental results





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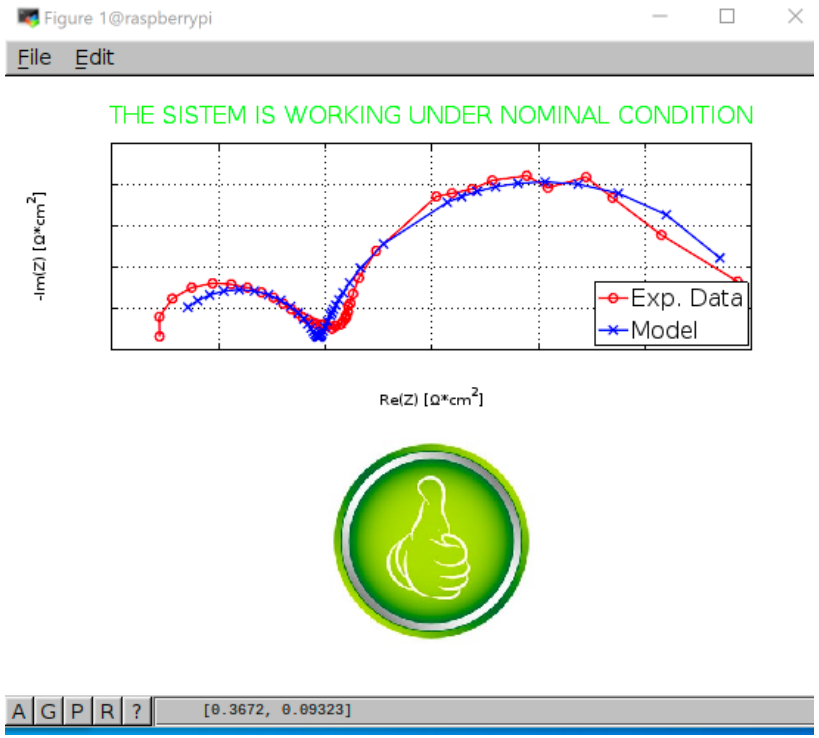
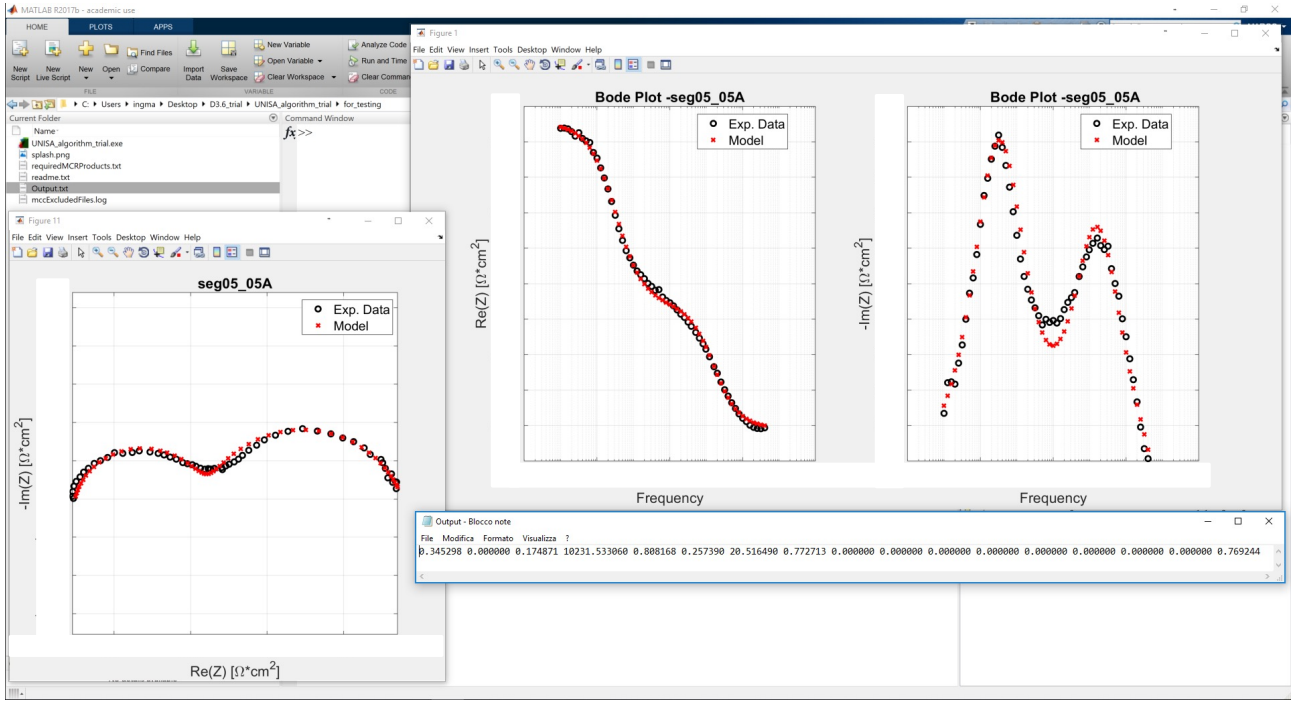
Switching converter-based actuation



First project of SOFC, thus the frequency range was suitably modified

(0.1 Hz up to 12 kHz, higher frequency limit)



Post-elaboration of data has been significantly improved

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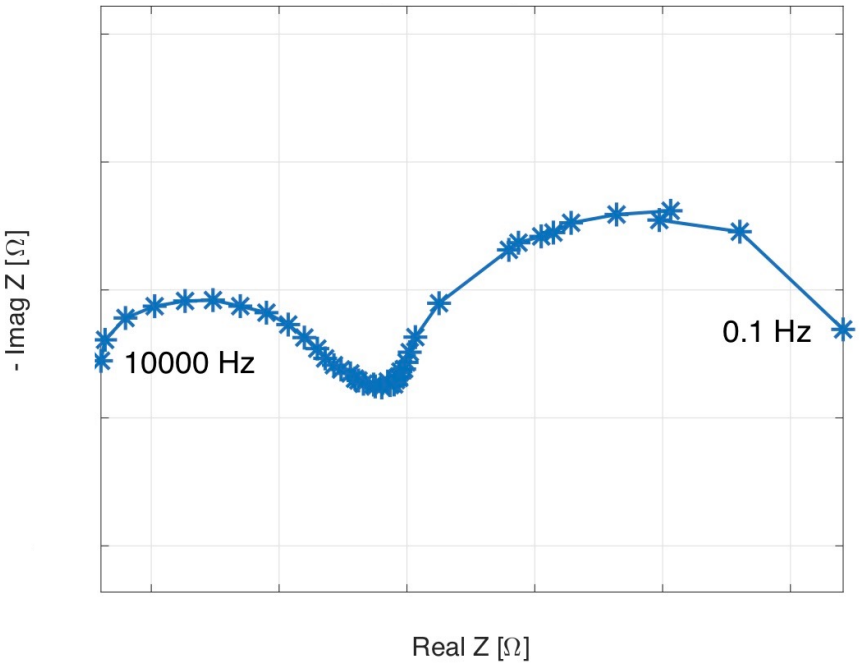
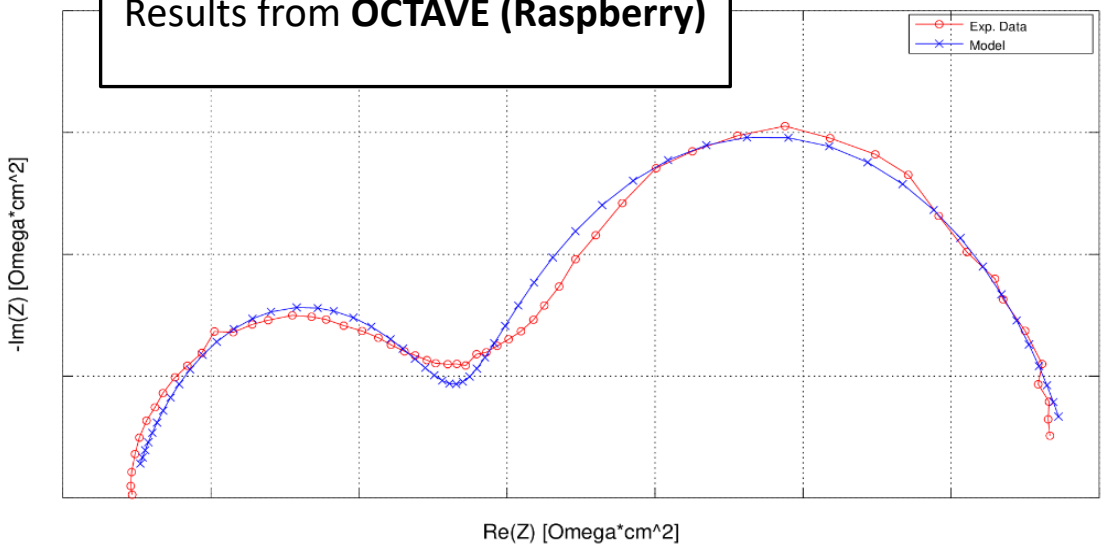
Switching converter-based actuation



Results from **OCTAVE (Raspberry)**



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EIS PERTURBATION ADD-ON

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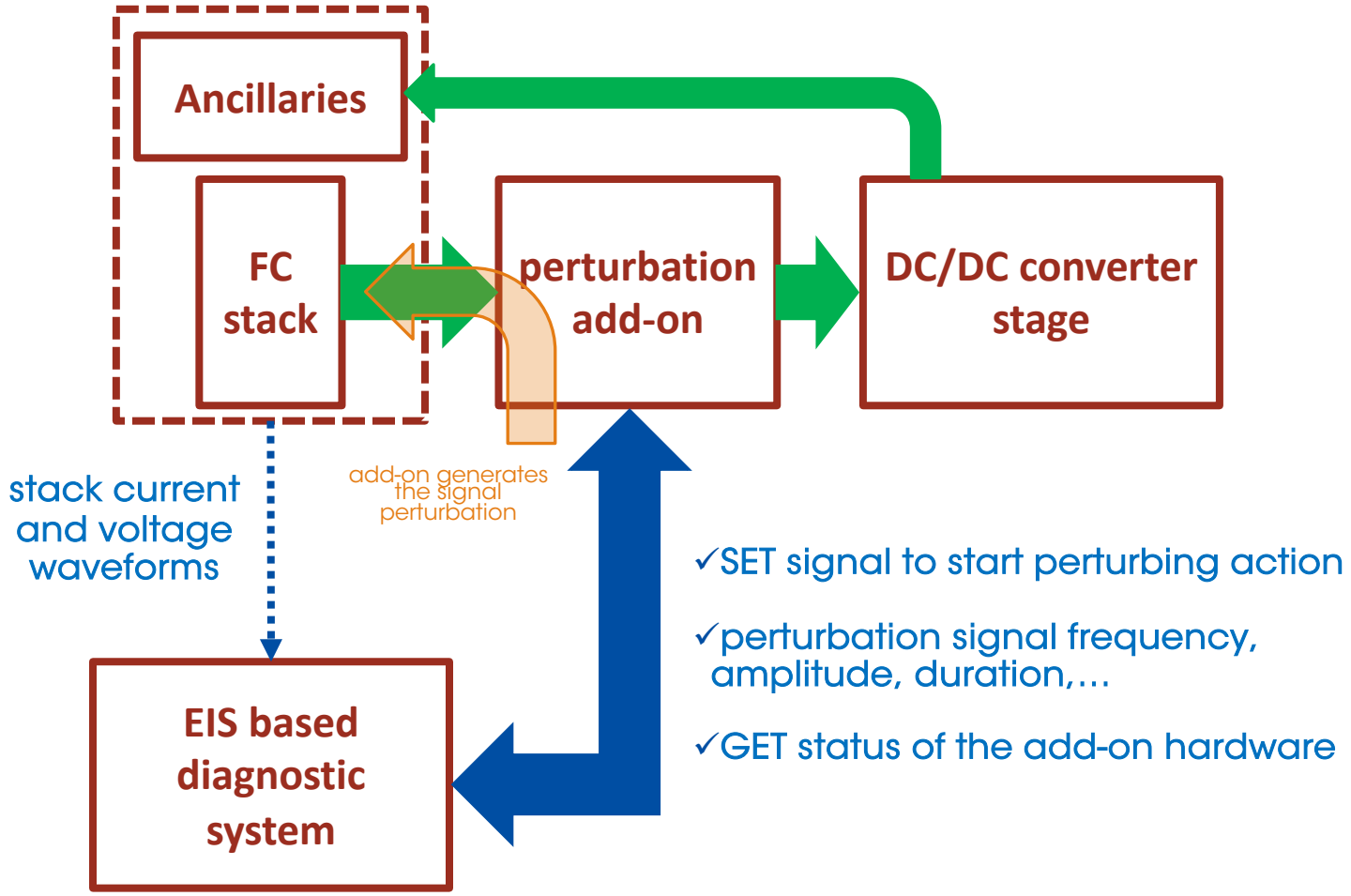
EIS perturbation injection strategies

Additional circuitry injecting the stimulus



Advantages

- no modifications of the DC/DC converter needed
- adaptation to any fuel cell system

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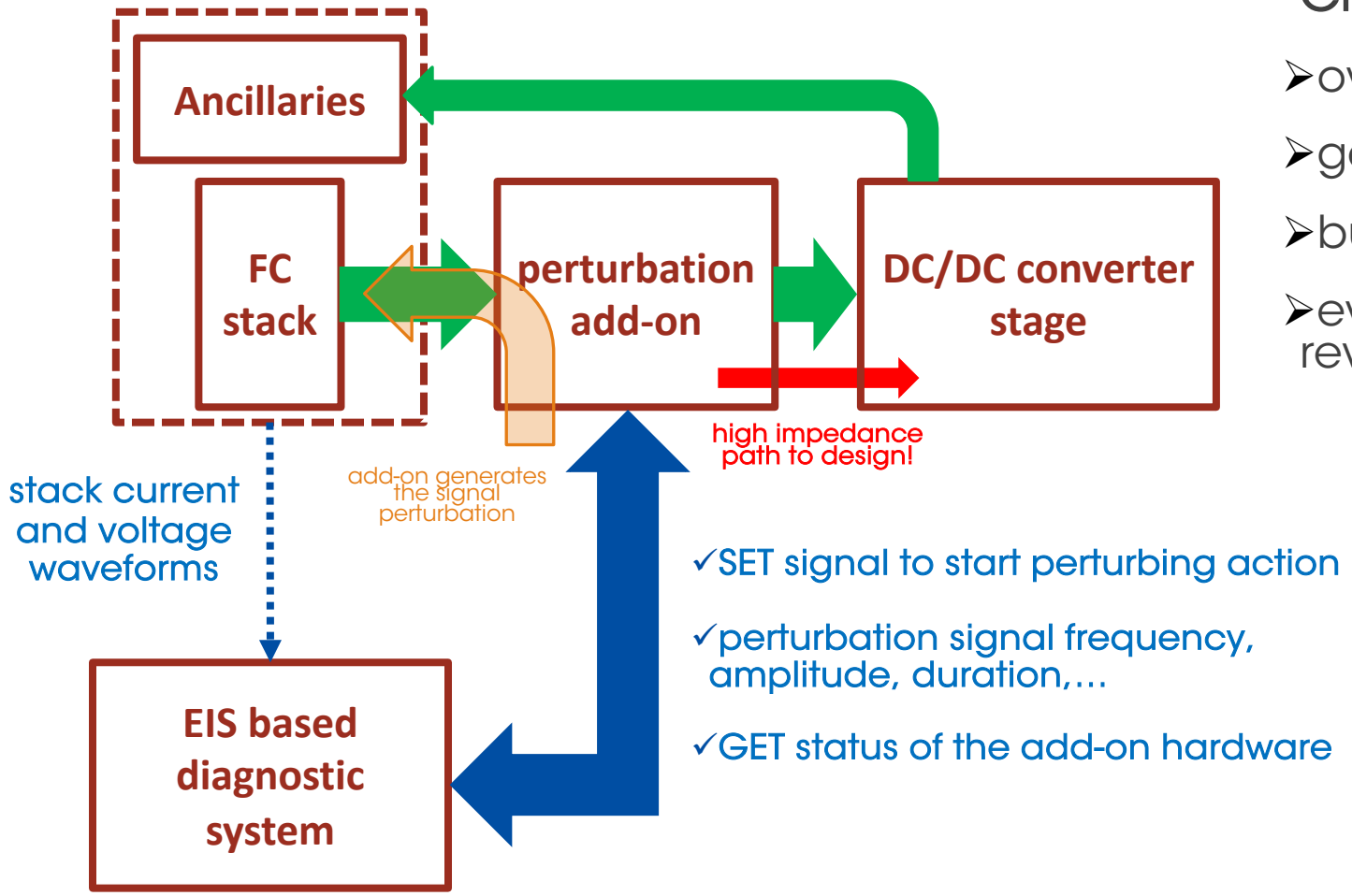
EIS perturbation injection strategies

Additional circuitry injecting the stimulus



Challenges and drawbacks

- overall conversion efficiency reduced
- generality of application that is only apparent
- bulky and heavy / difficult integration
- even more complicated design in case of reversible FC

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MDPC platform for on-field eis of fuel cells and electrolysers

DIAGNOSTIC TOOL EVOLUTION

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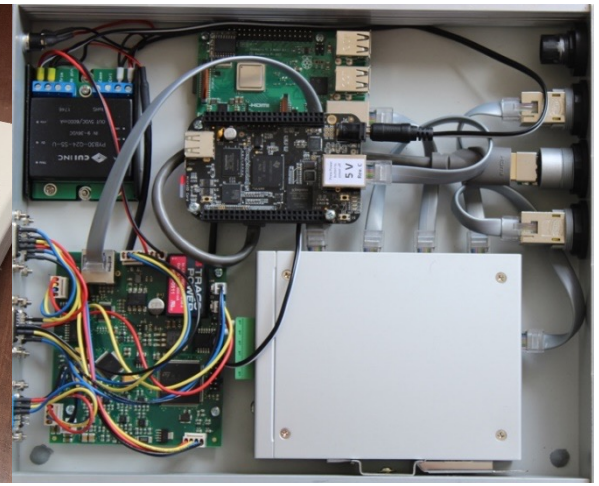
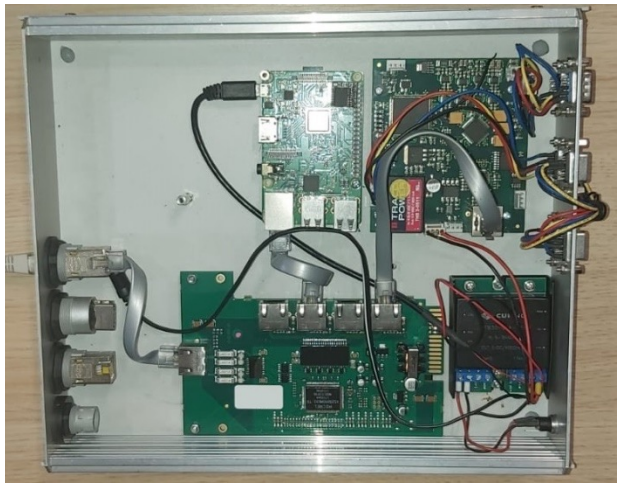
Diagnostic tool evolution

- supervise stimuli injection
- start/stop stimuli injection, injection duration, stimulus amplitude and frequency
- direct interaction with the power electronics controller through Ethernet TCP/IP channel (formerly PWM and CAN)
- Analog Front End (AFE) for stack current and voltage signal acquisition
- Acquisition of BOP variables for continuous monitoring functions implementation





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EIS device development

Main specifications

Analog Front End

- 1x analog input, stack voltage
- 1x analog input, stack current
- Resolution: 24bit

Digital I/O and communication

- 2x digital I/O
- 2x Ethernet port
- 1x USB port
- 1x RS-485 port
- 1x CAN port

Mechanical and EMC

- Metallic enclosure

EIS device prototypes available

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EIS device development

Main specifications

Analog Front End

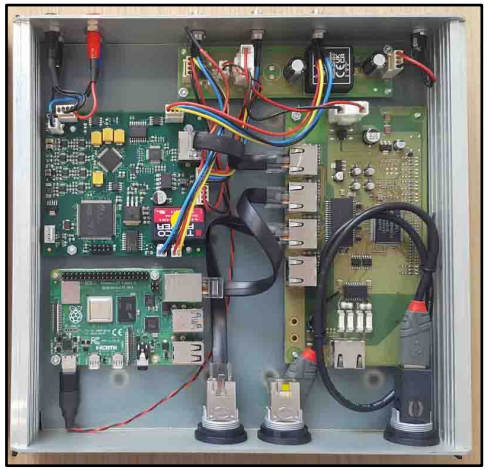
- 1x analog input, stack voltage
- 1x analog input, stack current
- Resolution: 24bit

Digital I/O and communication

- 2x digital I/O
- 2x Ethernet port
- 2x USB port
- 1x HDMI port
- 1x RS-485 port
- 1x CAN port

Mechanical and EMC

- Metallic enclosure



EIS device is integrated on a single board. Prototypes under validation

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Conclusions

- Hardware for on-line EIS-based diagnosis has been the subject of investigations
- Modifications of the existing DC/DC converter have been demonstrated to be effective
- Implementation through a hardware add-on to be connected between stack and DC/DC converter on course
- Sinusoidal and PRBS-based EIS have been implemented
- PEM and SOFC fuel cell systems have been tested
- application to electrolyzer/reversible systems under test

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eadinolfi@unisa.it

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