GENeric diagnosis Instrument for SOFC Systems (245128)

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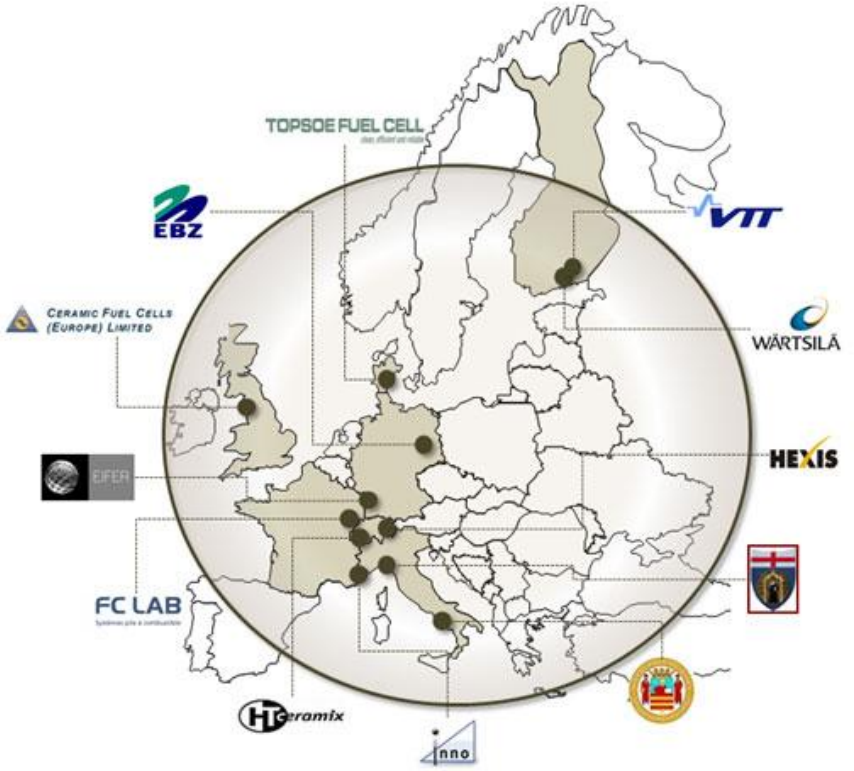
EIFER/Project Manager

Genius Partnership & Budget

3 years collaboration project: 01-02-2010 to 31-01-2013

Total budget: 3928 k€ ; Total funding: 2068 k€

Participant	Country	Type
EIFER	Germany	R&D
CFCL	England	Industry / SME
EBZ	Germany	Industry / SME
FC LAB	France	University
Hexis	Switzerland	Industry / SME
HTc	Switzerland	Industry / SME
TOPSOE	Denmark	Industry / SME
UniGE	Italy	University
UniSA	Italy	University
VTT	Finland	R&D
Wärtsilä	Finland	Industry / SME
Inno	France	Industry / SME



Objectives & Outcomes

Develop a "GENERIC" diagnosis approach that all SOFC developers could use and implement it in their systems according to their specific constraints:

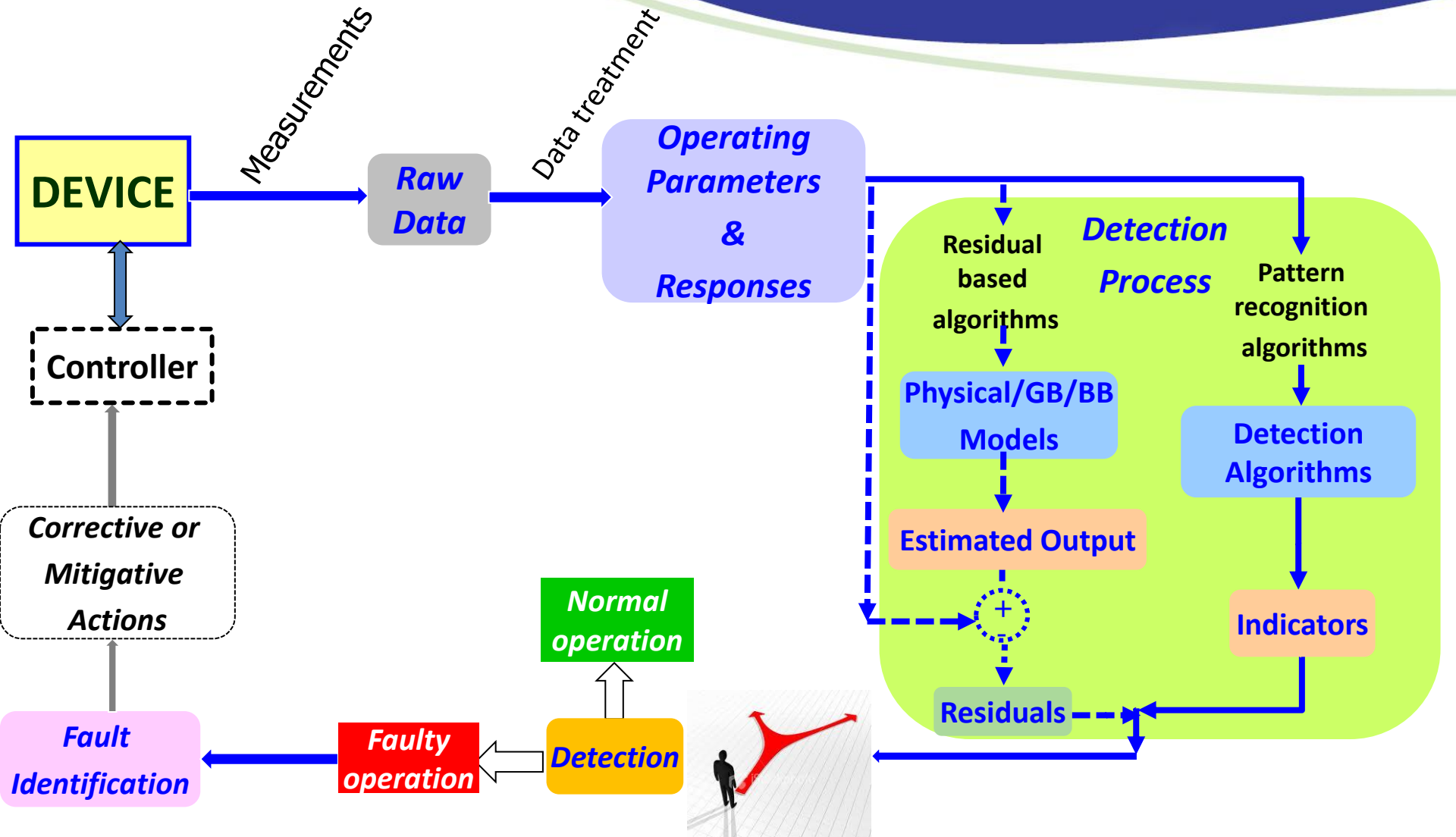
- **only using process values** (normal measurements and system control input parameters).
- taking into account **"on line"** or **"off-line"** situations.

Steps:

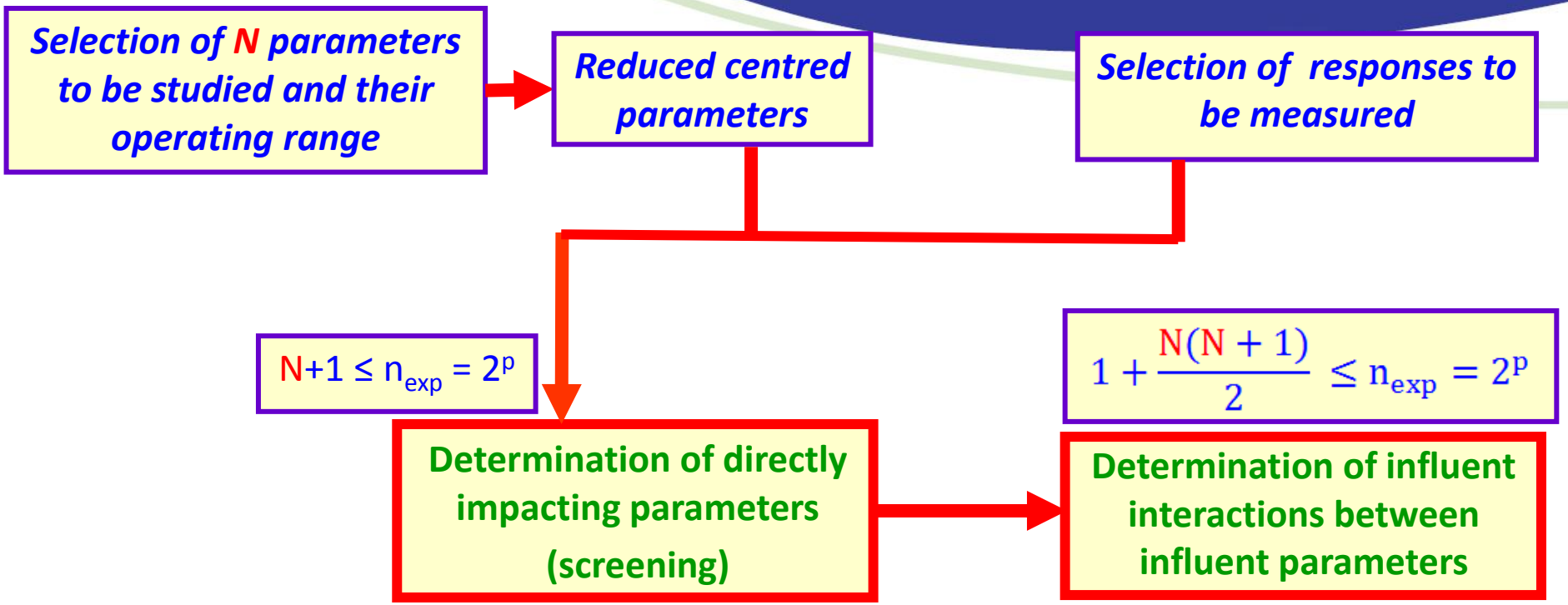
- Testing stacks & systems from 4 manufacturers, using commonly defined test plan based on "Design Of Experiment" methodology.
- 4 academic institutions will evaluate 3 types of algorithms (based on signal treatment and on residuals determination from either black box or grey box models) to define the optimal tool(s) for fault detection and identification.
- Iteratively adapting the defined test plan according to algorithm developers' needs.
- Developing a diagnostic protocol integrating the best algorithm(s).

- Validate it (them) on 3 SOFC systems, either off-line or on-line.

Diagnostic Methodology

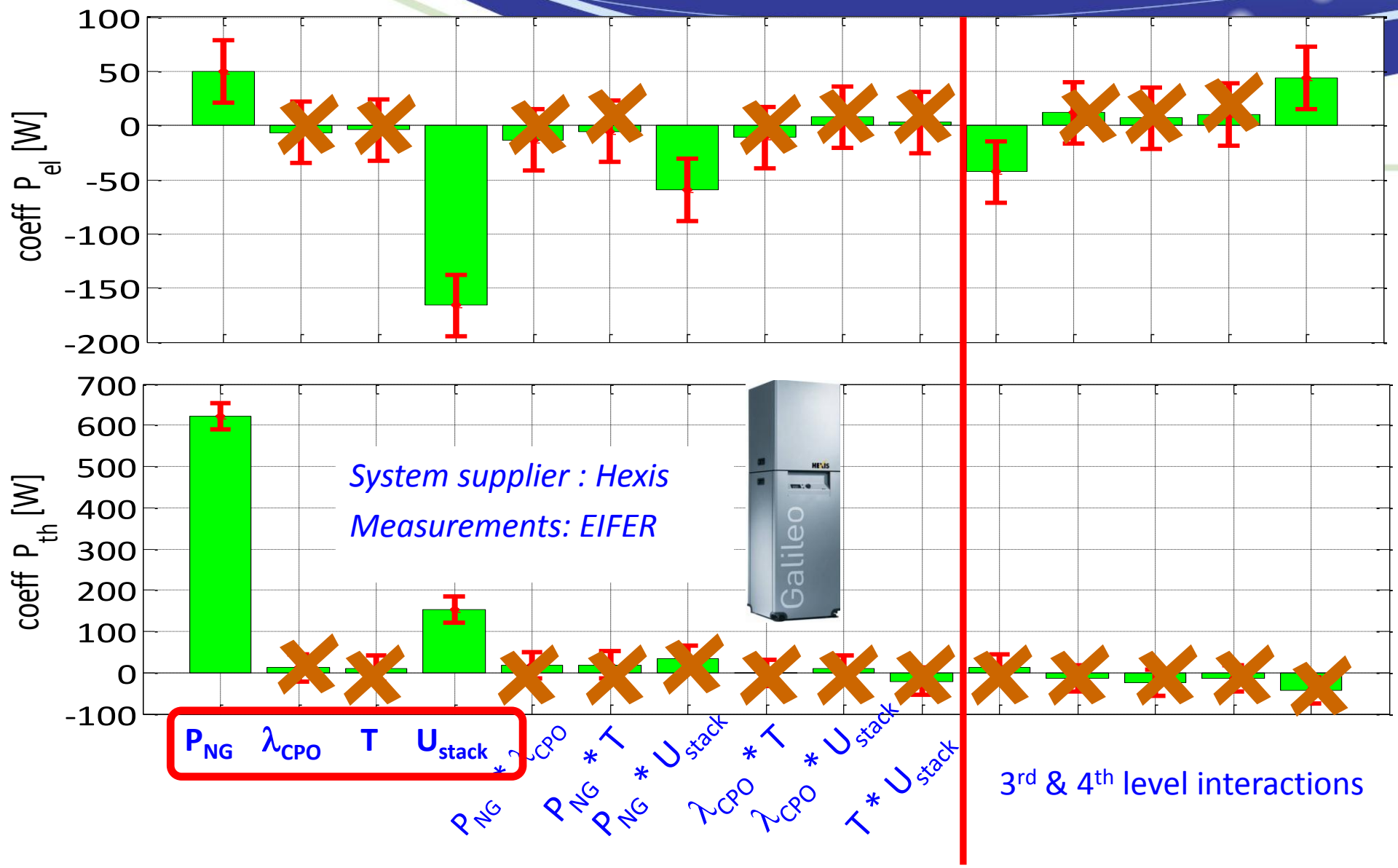


DoE methodology

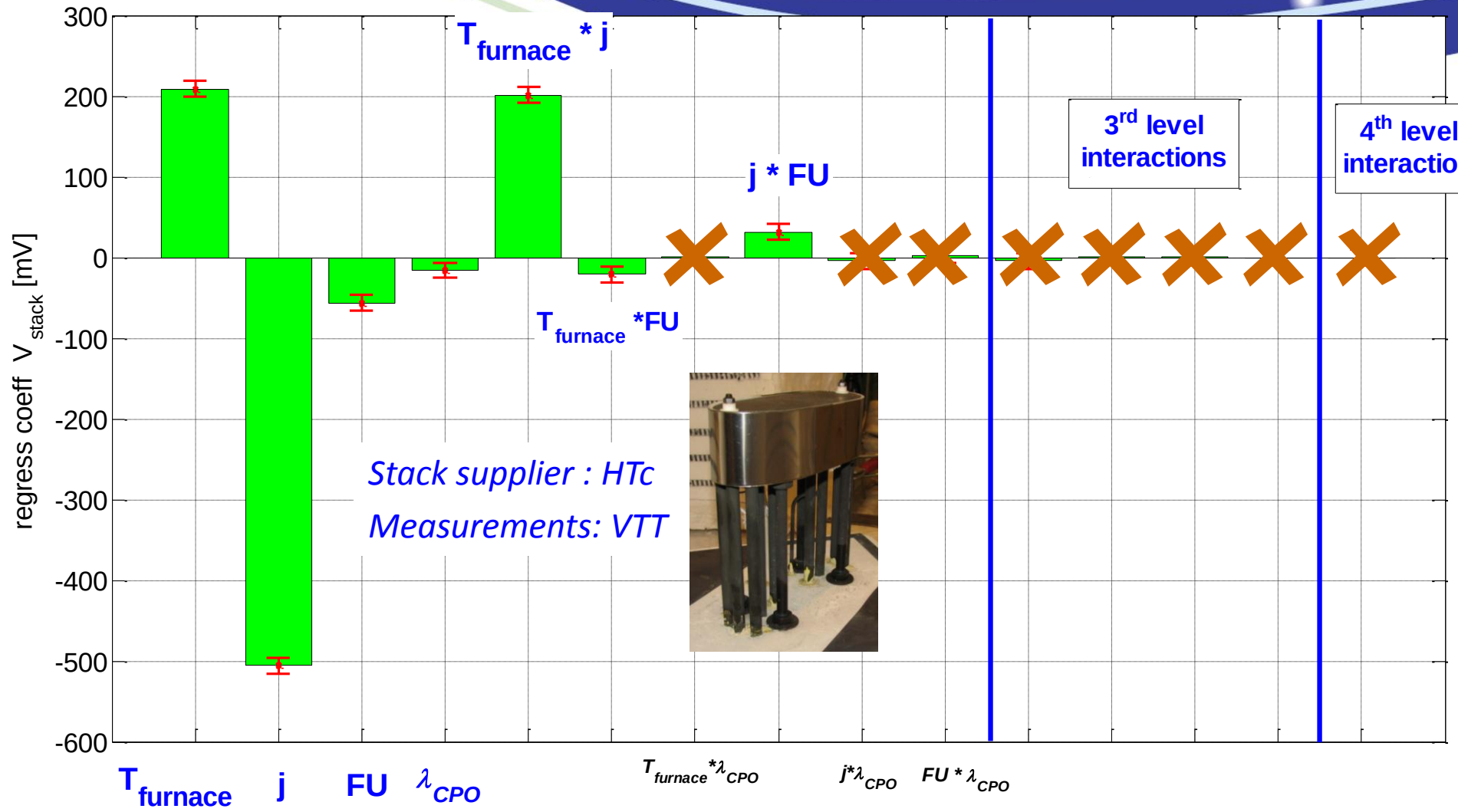


- >3 experiments in the centre of the domain so as to:
  - Evaluate measurement's reproducibility ⇒ effect significance.
  - Detect potential ageing during experiment.

Results of DoE

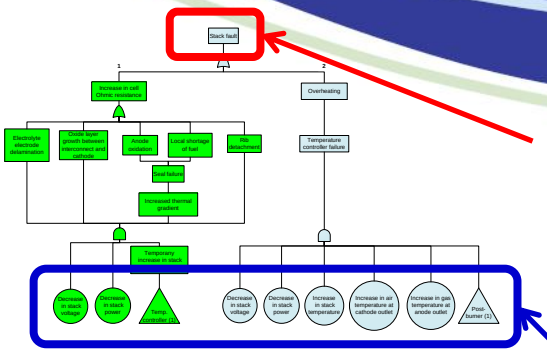


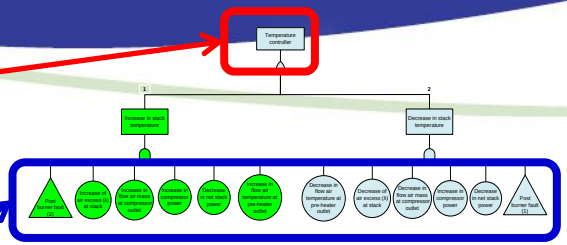
WP 3: DoE analysis of stack voltage (VTT experiments on HTc stack)



Residual based diagnostic approach

- Fault tree analysis
- Signature matrix
- Black/grey box Model
- Residual calculation
- Threshold definition (e.g.: ± 2 σ, ± 3σ)
- Inference





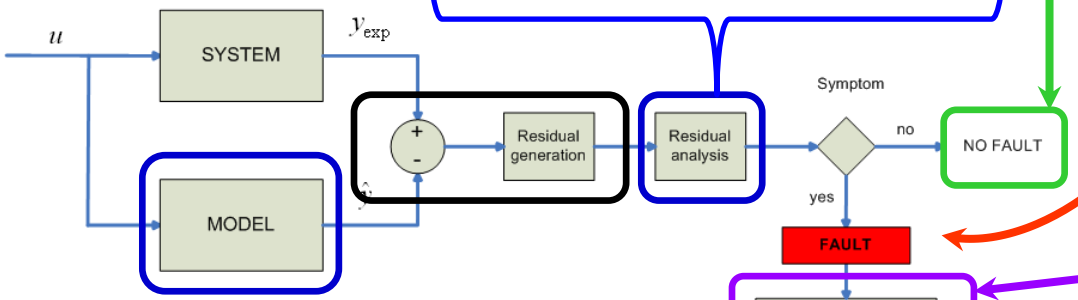
Fault

Symptoms *(measured values)*

	s_1	s_2	s_3	s_4	s_5	s_6	s_7	s_8	s_9	s_{10}	s_{11}	s_{12}	s_{13}	s_{14}	s_{15}	s_{16}	s_{17}
f_1	0	1	1	0	1	1	1	1	0	1	0	0	0	0	0	1	1
f_2	0	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0
f_3	0	1	1	0	1	1	0	1	0	1	0	0	0	0	0	1	1
f_4	0	1	1	0	0	0	0	1	0	1	0	0	0	0	0	0	0
f_5	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0
f_6	1	1	1	0	1	1	0	1	0	0	1	1	1	0	0	1	1

No match

At least one match

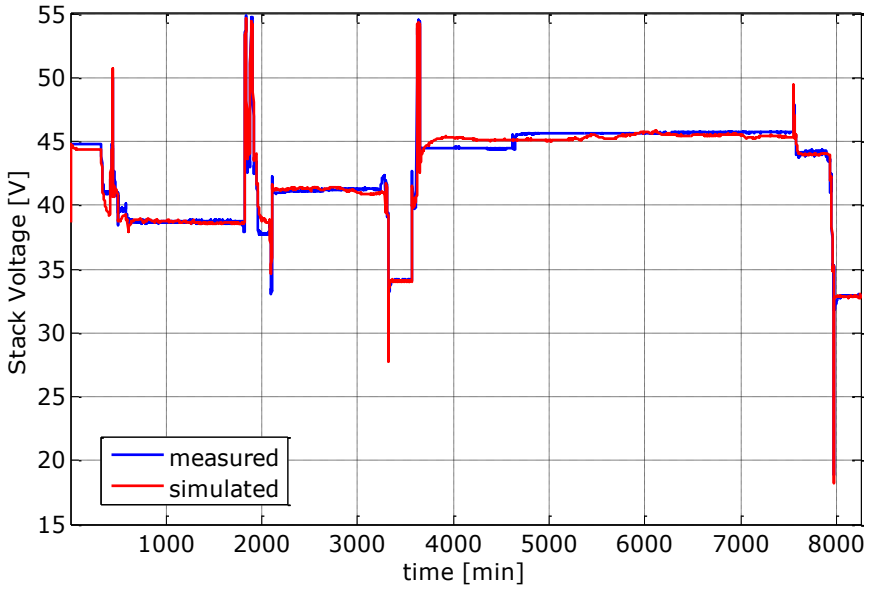


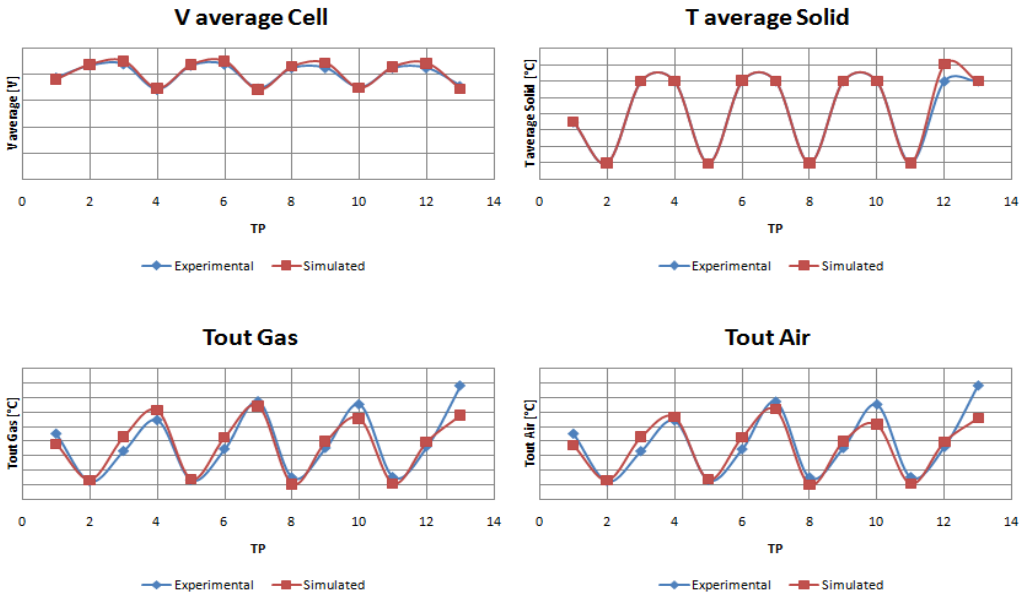
Unique match

Residual based algorithm performance

Stack supplier : TopSoE

Measurements: TopSoE

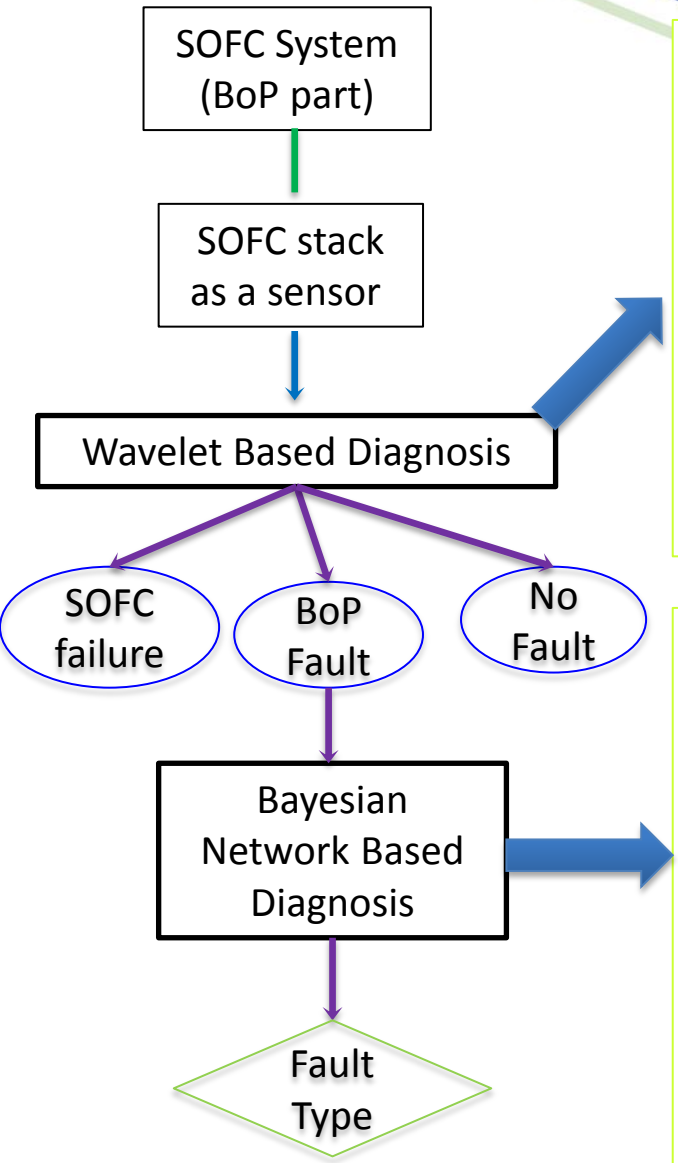




Simulations: Black box model (UniSA)

Simulations: Grey box model (UniGE)

Pattern recognition based algorithm performance



Function:

1. Check the state of health of a "special" sensor – SOFC stack;
2. BoP fault detection.

Principle:

Decompose the SOFC voltage signal by wavelet transform method. The distribution of energies of the subsignals can indicate the state of health and the abnormal operating condition of the SOFC.

This **algorithm** has been **validated on data from both test rounds at VTT on HTc stack** (requested signal sampling rate is at least 1Hz)

Function: BoP fault identification.

Principle:

Use experimental data to train the Bayesian Network and obtain a meta-model of SOFC.
Use this model to estimate the operating variables – Fuel & Air flow rates and utilisations, Furnace & Stack temperatures.

Fault to diagnose: Low current density and high FU.

Validation result: (VTT data)

67% of the1449 samples measured in such a faulty operating mode **can be identified by the Bayesian Network model**.

Alignment to MAIP- AA3 & AIP 2008 – Topic 3.3

⇨"The aim will be to deliver (…) reliable control and diagnostics tools both at a component and at system level.“

⇨ "Applied research activities are directed towards developing components and sub-systems with improved performance, durability and cost (…)."

Main project objective: **develop a Generic diagnostic algorithm integrated in a standard hardware equipment** to detect faults and prevent failure before occurrence. ⇒ better system reliability ⇒ **increase system lifetime**.

Alignment to MAIP- AA3 & AIP 2008 – Topic 3.3

"(…), substantial effort is needed to address lifetime requirements of 40,000 h for cell and stack, as well as competitive costs..."

The approach will allow to detect faults and to prevent failure before their occurrence ⇒ **better system reliability** ⇒ **improve the competitiveness** of fuel cell vs other µ-CHP technologies by **increasing availability ratio & system lifetime**.

⇨"Improved prediction and avoidance of failure mechanisms".

⇨"Development of strategies for recovery of cell and stack performance"

Experimental evaluation of failure mechanisms' signatures & development of new data analysis methods ⇒ **identify the effect of each failure mechanism** from normal base-line ⇒ **early detection** ⇒ **system operating parameters optimisation** ⇒ **degradation minimisation**.

Cross-cutting issues: Education, Training & Dissemination

Education & Training:

- 4 PhD students working on the project, 2 of them spent/are spending time at partners facilities.
- 1 PhD defended (P. de VASCONCELLOS CARDONE, UniGE, 04/2012), 1 to be defended (K. Wang, FC Lab-EIFER)

Publications & Communications:

- 2 publications.
- 3 presentations at conferences.
- 2 presentations in workshops.

Organisation of workshops:

- Workshop in Viterbo (M19) about degradation causes and effect.
- Common workshop with D-CODE project (M28) in Belfort: 10 speakers, 50 attendees.

Website: http://genius-jti-project.eu/

Enhancing cooperation and future perspectives
Technology transfer and collaboration

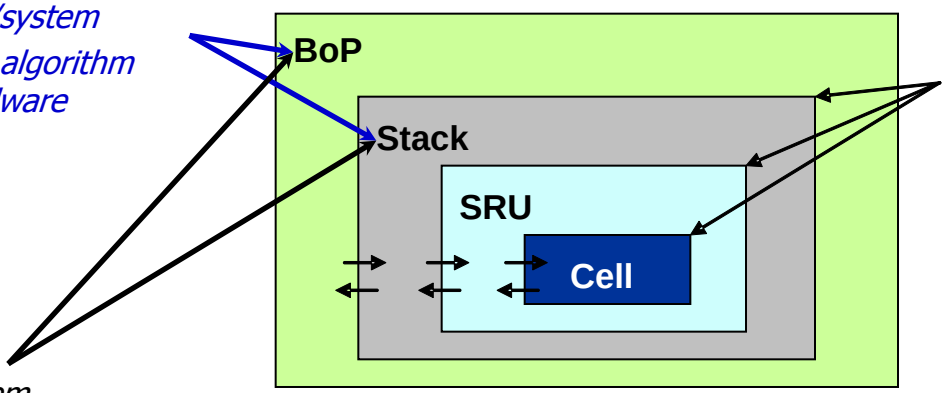
- **Collaborations**

GENIUS

Object: SOFC system

Sensor: SOFC stack/system

Outcome: diagnosis algorithm integrated with hardware



DESIGN

Object: SOFC (from SRU to stack)

Sensor: various levels

Outcome: Method and signatures as input for a diagnostic tool + recovery strategy recommandations

D-CODE

Object: PEMFC system

Sensor: Electrochemical Impedance Spectroscopy made by the DC/AC inverter

Outcome: diagnosis algorithm + Impedance measurement hardware

- **Technology Interfaces**

➡Enhanced interface between stack/system manufacturers and diagnosis algorithm developers

Future perspectives: *Generalization to all FC and H_2 technologies and AA*