



SAPPHIRE

System Automation of PEMFCs with Prognostics and Health management for Improved Reliability and Economy

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*Programme Review Days 2016
Brussels, 21-22 November*

Project Information

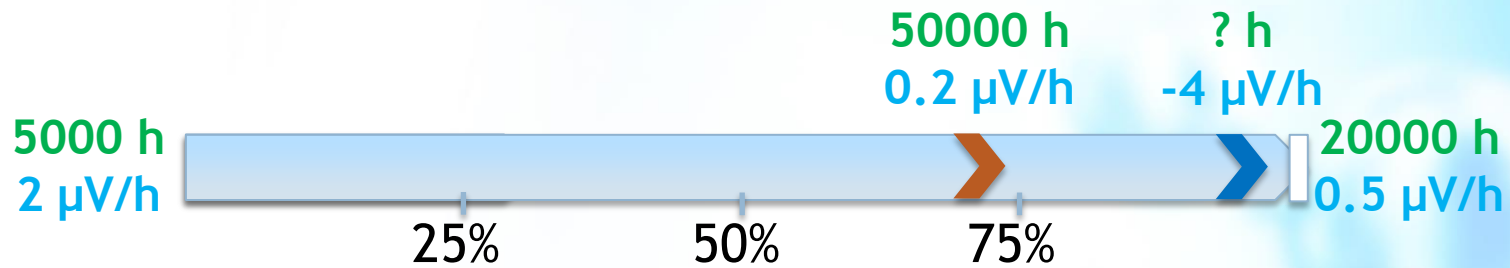
Call topic	Robust, reliable and cost effective diagnostic and control system design for stationary power and CHP fuel cell systems
Grant agreement number	325275
Application area	Stationary Power Generation and CHP
Start date	May 1, 2013
End date	April 30, 2016
Total budget (€)	3 269 417,10
FCH JU contribution (€)	1 745 140,60
Other contribution (€, source)	~650 000 €, Norwegian Research Council
Stage of implementation	100% (ended April 30, 2016)
Partners	SINTEF; EIFER; ENSMM/UFC; FESB; ZSW; Dantherm Power (<i>now Ballard Europe</i>)

- Increase lifetime of fuel cells in μ CHP
- Use prognostics to estimate Remaining Useful Life
- Design controllers to increase lifetime
- Apply on current stack technology
 - No development of new membranes, catalysts etc.
 - Compare to e.g. KeePEMalive
- State of the art at project start:
 - Guaranteed *5000 hours*
 - Degradation rate per cell $2 \mu\text{V}/\text{h}$
 - Regulatory control
- Target market: domestic applications



PROJECT PROGRESS/ACTIONS - Durability

 Achievement to-date
 % stage of implement.



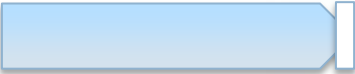
Aspect addressed	Parameter (KPI)	Unit	SoA 2016	FCH JU Targets		
				Call topic	2017	2020
Durability	Lifetime	h	≈50000	20000	N/A	30000
	Cell degradation rate	μV/s	0.2 μV/h			

Future steps:

- Basic research in rejuvenation mechanisms
- How long does it last? (Tested 7500 hours)
- Does it promote other degradation modes?

PROJECT PROGRESS/ACTIONS - Durability

Achievement to-date
% stage of implement.

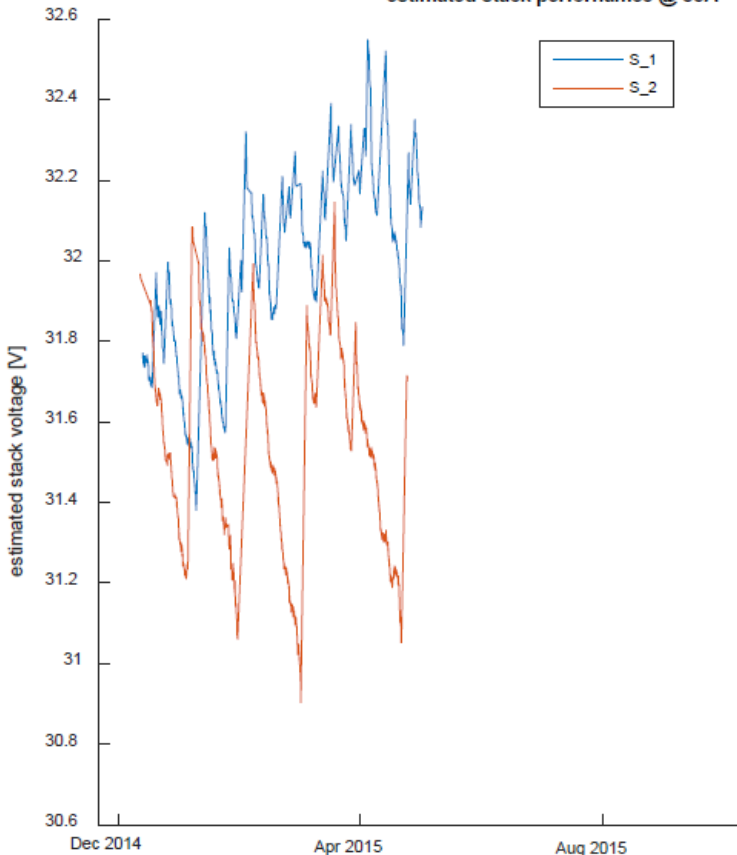
5000 h 2 μ V/h  20000 h 0.5 μ V/h

50000 h
0.2 μ V/h

? h
-4 μ V/h



estimated stack performance @ 35A



1st test campaign

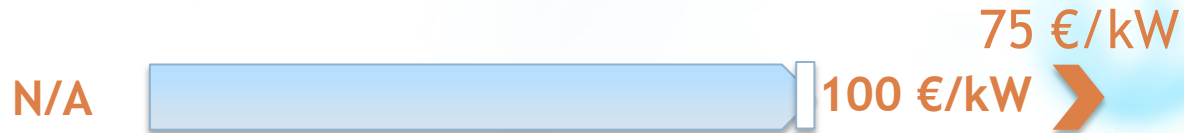
- Computer crashes
- Forced restarts
- Rejuvenation detected

2nd test campaign

- Fixed computer
- Scheduled restarts
 - Only system 2
 - Only for 1000 h
- Forced restarts on system 1 after 2000 h

PROJECT PROGRESS/ACTIONS - Additional cost of control system

➤ Achievement to-date
▮ % stage of implement.



Aspect addressed	Parameter (KPI)	Unit	SoA 2016	FCH JU Targets		
				Call topic	2017	2020
Cost	Additional cost of control system	€/kW	75	100	N/A	N/A

Future steps:

- 68 € pressure sensor on 900 W system
 - All other control implemented in LabVIEW, no extra cost
- Considered only *electric* power (even if it is CHP)
- Much cheaper differential pressure gauges are available

SYNERGIES WITH OTHER PROJECTS AND PROGRAMMES



Interactions with projects funded under EU programmes

KeepEMalive

Shared cell degradation data

D-CODE

Established online EIS diagnostic groundwork

Re4cell

Invited to workshop

Second Act

Invited to workshop

Giantleap

Follow-up project applied on city buses

Interactions with national and international-level projects and initiatives

Diapason 1 & 2

French projects, established prognostics groundwork

Public deliverables

- D2.5, Test protocols
- D2.6, Measurement techniques
- D5.1/2/3, Diagnostics
- D6.1/2, Prognostics
- D7.3, Control evaluation

Conferences/Workshops

- Organised 2 workshops
- Participated to 12 conferences and 2 workshops of other projects

Social media



Publications: 23 at conferences, 3 in journals, 2 PhD theses

- Bezmalinović & al., *Characterization of PEM fuel cell degradation by polarization change curves*, *J. Pow. Sour.* 294 (2015) 82-87.
- Lechartier & al., *Proton exchange membrane fuel cell behavioral model suitable for prognostics*, *Int. J. Hydr. En.* 40 (2015) 8384-8397.

Patents: 2

- Zenith & al., *Control of an electrochemical device with integrated diagnostics, prognostics and lifetime management*, WO2016059203A1

Exploitation

- Consortium patent licences
 - Handled by EdF & ZSW
- Licensing of EIFER patent
- Ballard product innovation
 - Starting 2017
- Prognostic and control SW
 - FCLAB and SINTEF
 - Freely available
- CFD improvements to flow fields for ZSW

Impact

- All quantitative targets in call were exceed
- On-line catalyst regeneration techniques
- Boosted lifetime for μ CHP
- What about automotive?
 - See *Giantleap* for further developments

Thank You!

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