

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

SAPPHIRE 

325275

Federico Zenith

SINTEF

[www.sapphire-project.eu](http://www.sapphire-project.eu)

# PROJECT OVERVIEW

- **Topic:** Robust, reliable and cost-effective diagnostic and control systems design for stationary power and CHP fuel cell systems
- **Area:** Stationary power production and CHP
- **When:** May 2013 - April 2016
- **Budget:** 3.25 M€ (FCH: 1.75 M€, NFR: 650 k€)

- **Consortium:**



- **Idea:** *increase life of PEMFCs in  $\mu$ CHP with smart control; optimise with prognostics*
- **Progress:** 85% through project; on time

# PROJECT TARGETS AND ACHIEVEMENTS

Programme objective/target	Project objective/target	Project achievements to-date	Expected final achievement
<b>MAIP</b>			
30 000 h	20 000 h (current tech)	Ran 9000 h <i>Projected</i> 50 000 h	> 20 000 h
<b>AIP</b>			
20 000 h (current tech)	20 000 h (current tech)	Ran 9000 h <i>Projected</i> 50 000 h	> 20 000 h
< 100 €/kW	< 100 €/kW	136 €/kW	68 €/kW

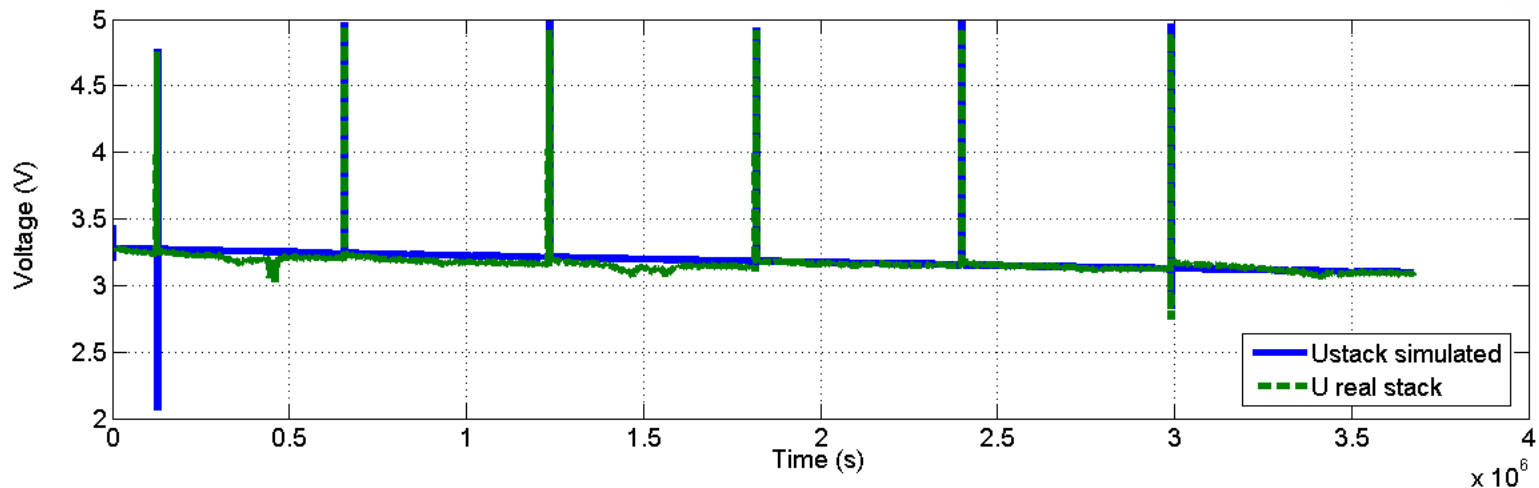
# PROJECT TARGETS AND ACHIEVEMENTS

- Control/diagnostic system for:

- Optimal air bleed
- Humidity control
- Anodic lambda

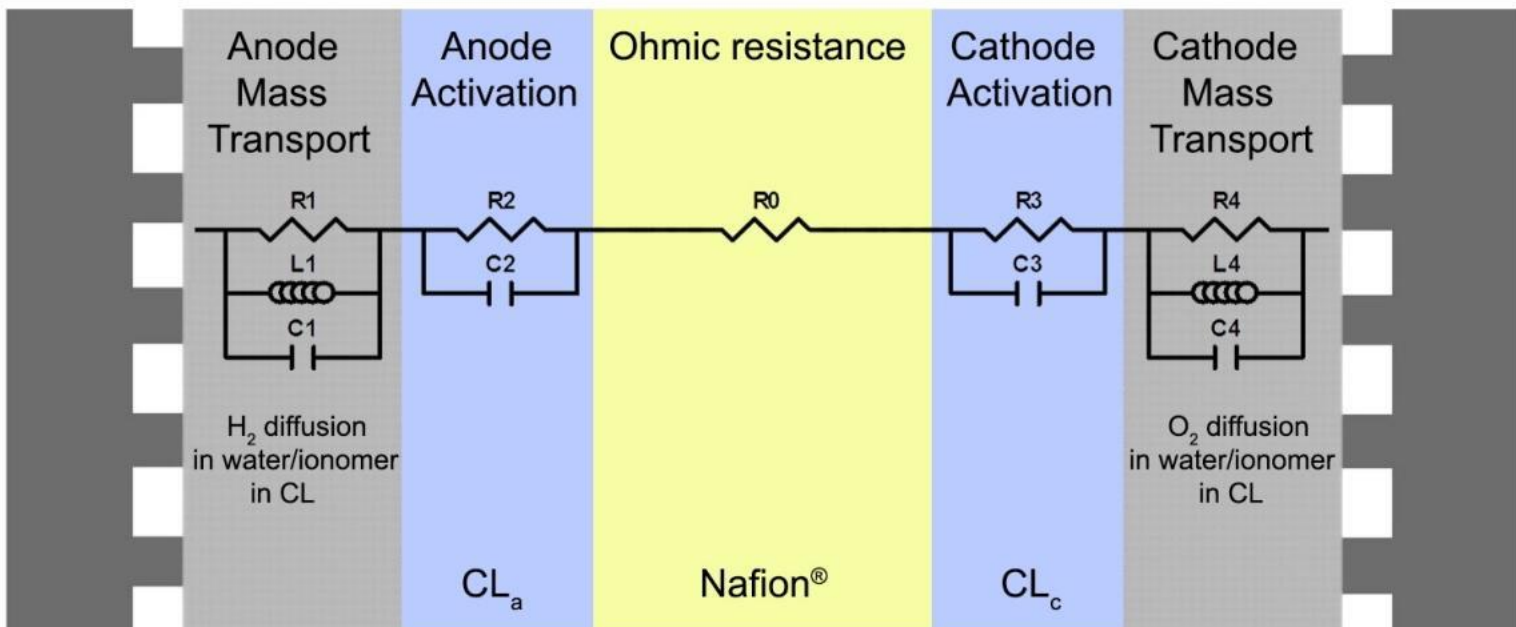


- High-precision prognostics learning until 2<sup>nd</sup> peak, then prediction



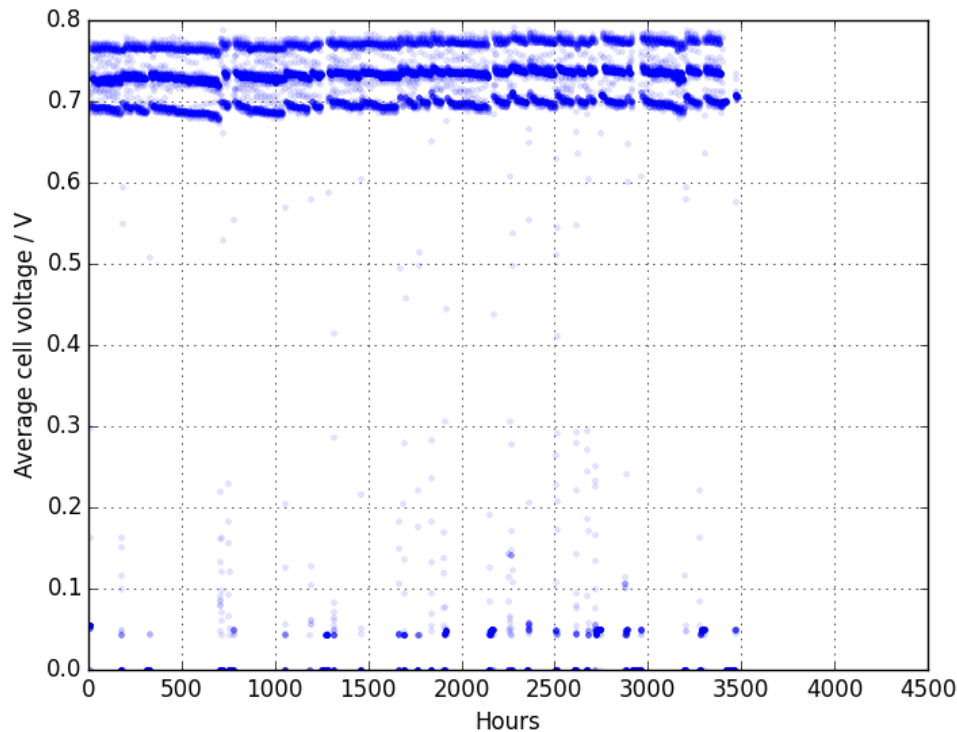
# PROJECT TARGETS AND ACHIEVEMENTS

- Testing protocols
  - Long-term and accelerated
- New equivalent circuit model
  - $R_4$  is a good prognostic variable



# PROJECT TARGETS AND ACHIEVEMENTS

- 3000+ h tests on 2  $\mu$ CHP systems
  - Each previously used 5000 h



- Nominal:  
2  $\mu$ V/h
- Measured:  
0.4  $\mu$ V/h

# RISKS AND MITIGATION

- Few degrees of freedom in  $\mu$ CHP
  - Control can do little optimisation
  - Little integration with prognostics
  - Focus on rejuvenation techniques
    - Regular start-stops?
    - Variable load?
- Can the low-degradation in Dantherm's tests be replicated?
  - New tests to identify direct causes
- All original targets stand ✓

# SYNERGIES WITH OTHER PROJECTS AND INITIATIVES

- Additional financial support from Norwegian Research Council (650 k€)
- Previous projects
  - D-Code (EIS with DC/DC converters)
  - Diapason 1 & 2 (PEMFC diagnostics)
  - KeePEMalive experimental data
- Current collaborations
  - ReforCELL (reformers for  $\mu$ CHP)
  - Invited to workshop to present SAPPHIRE



# DISSEMINATION ACTIVITIES

- 14 international conference contributions
  - HFCNC, EAR, UECT, CARISMA (× 2), IDHEA, VPPC (× 5), IEEE PHM, EFCF, ADCHEM
- 2 articles published (+1 submitted)
- Invited session at VPPC2014
  - "Upgraded" workshop
- Programmed: Hanover Fair 2016
  - "Final event" at high-impact industrial fair
- Two patents being sought
  - One whole consortium, one EIFER only

# EXPLOITATION PLAN/EXPECTED IMPACT

- Main Results:
  - A lot of degradation is not irreversible as thought
  - Equivalent model shows good prognostic variables
  - Precise and validated prognostics
  - New control techniques for humidity, CO, anodic  $\lambda$
  - Minimal new equipment (one pressure sensor)
- Impact
  - Long-term degradation reduced by factor 10
- Exploitation
  - Dantherm embeds new technology in their  $\mu$ CHP
  - Technology may be licensed to other companies