B1301*

INVESTIGATION OF 2-MW PEMFC POWER PLANT FOR HYDROGEN RECOVERY FROM CHLORINE INDUSTRY

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SUMMARY

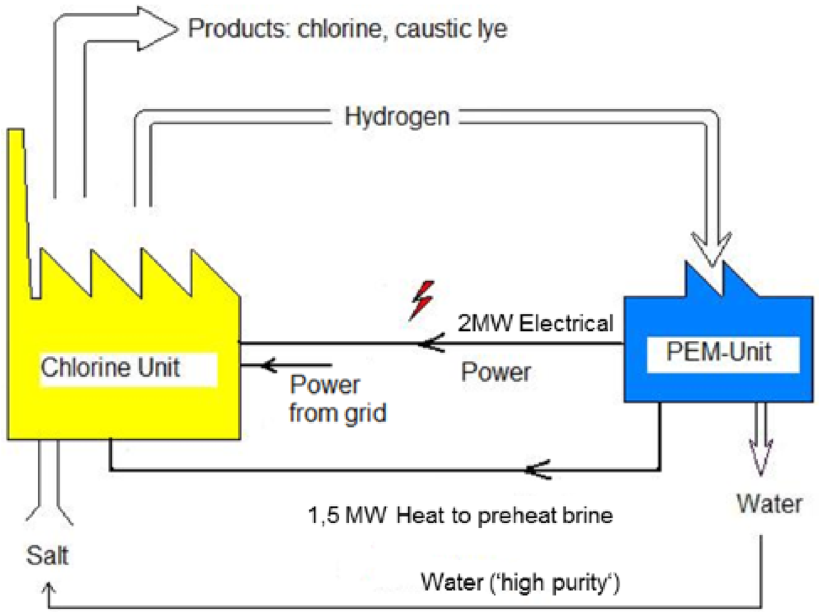
- ✓ DEMCOPEM-2MW PROJECT
- ✓ PLANT MODELLING
  - ✓ PLANT LAYOUT
  - ✓ MODELS VALIDATION
- ✓ PLANT OPERATION
  - ✓ REVERSIBLE-IRREVERSIBLE VOLTAGE DECAY
- ✓ CONCLUSIONS

DEMCOPEM-2MW EU PROJECT

Design, construction and demonstration of a combined heat and power (CHP) PEMFC power plant ($2MW_{DC\ el}$)

and

integration into a chlor-alkali industrial plant recovering byproduct hydrogen



OBJECTIVES (2015-2019)

- **High net conversion efficiency** (> 50% electric and > 85% total)
- **Long lifetime** of system and fuel cells (16,000 h up to 40,000 h target)
- Development of large-volume **manufacturing process** for high-quality MEAs
- **Economical plant design** (< 2500 €/kW_e)
- Fully **automated operation**
- Ensure plant reliability by developing protocols for **fuel cells monitoring and rapid replacement** of faulty stacks (on-stream availability of > 95%)
- Contribute to the general goals of the FCH-JU for installed fuel cell capacity

PROJECT PARTNERS

Johnson Matthey Fuel Cells – *the power within*

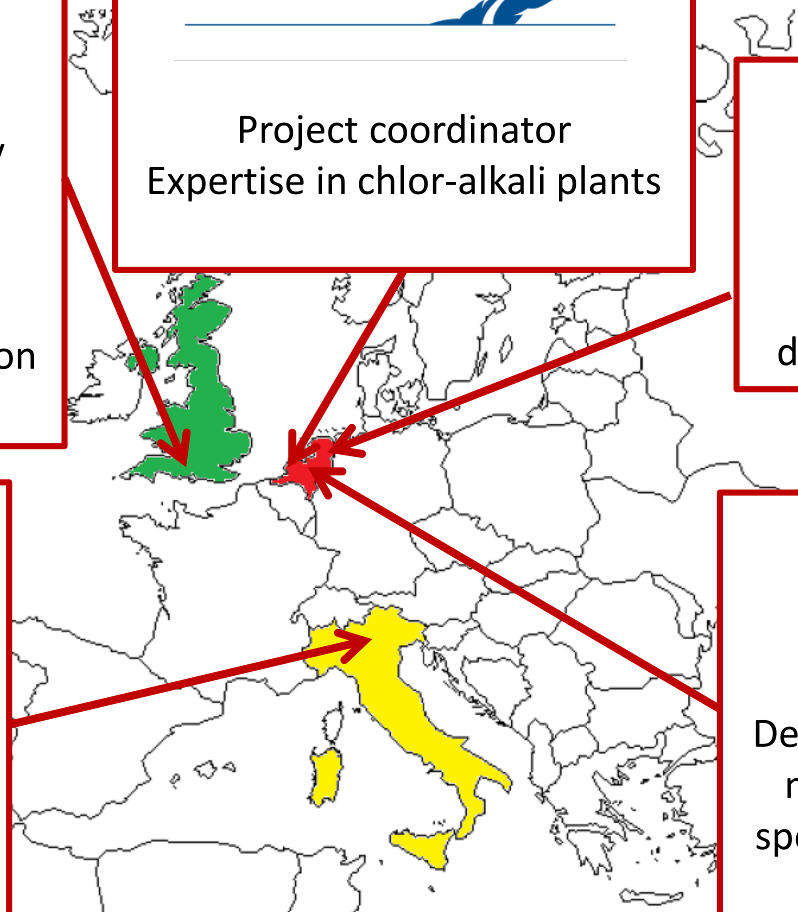
High quality MEA assembly
Manufacturing process development
Performances, robustness, lifetime and costs optimization

AkzoNobel

Project coordinator
Expertise in chlor-alkali plants

Nedstack – PEM FUEL CELLS – *To be sure.*

PEM fuel cell stack development and production



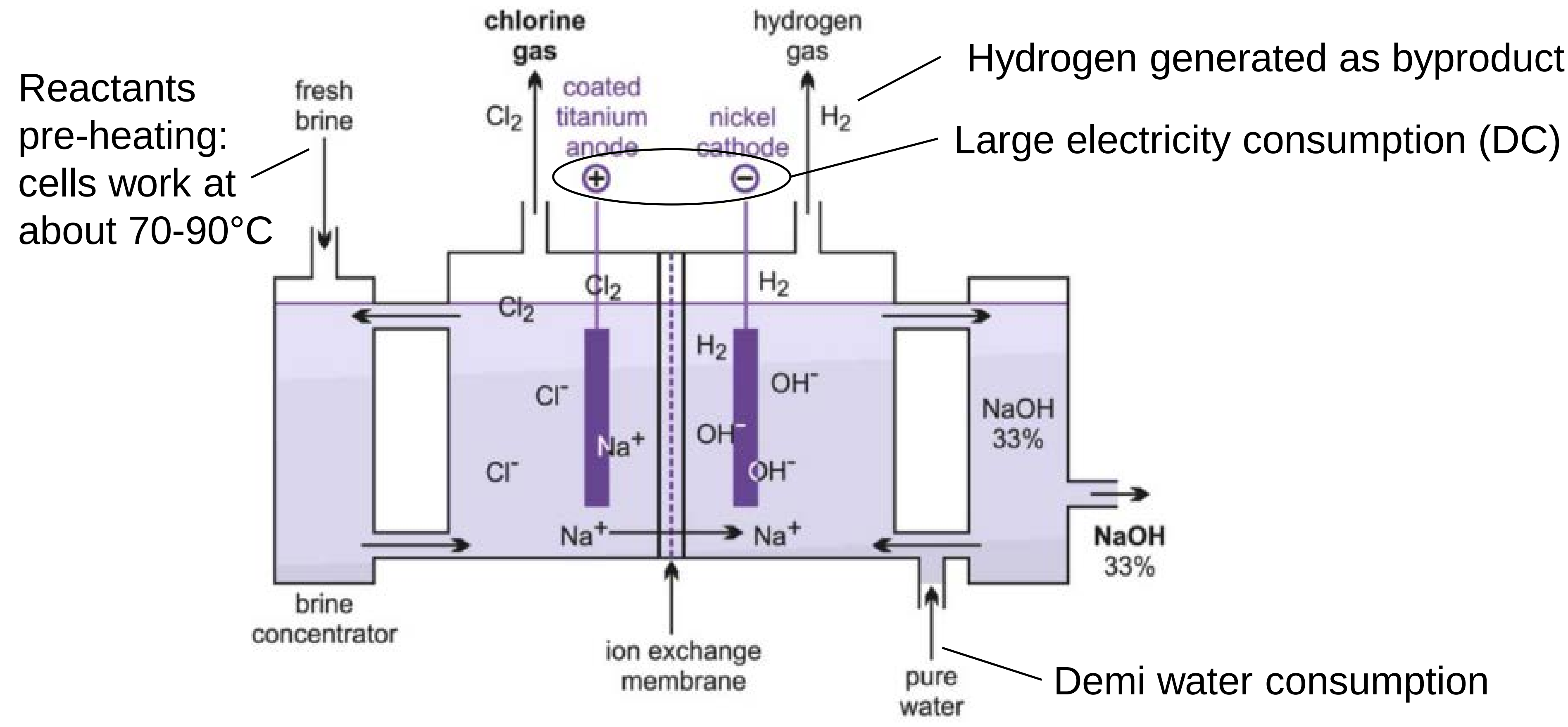
POLITECNICO MILANO 1863

Power plant simulation model development, calibration and validation
Analysis of experimental measurements

MTSA TECHNOPOWER

Development, production and maintenance of customer-specific equipment for energy processes

The Chlor-alkali process is suitable for integration with low temperature PEMFC: large need of heat and electricity



PREVIOUS PROJECTS: PEMFC PLANTS SCALE-UP

Installation is in **China:**

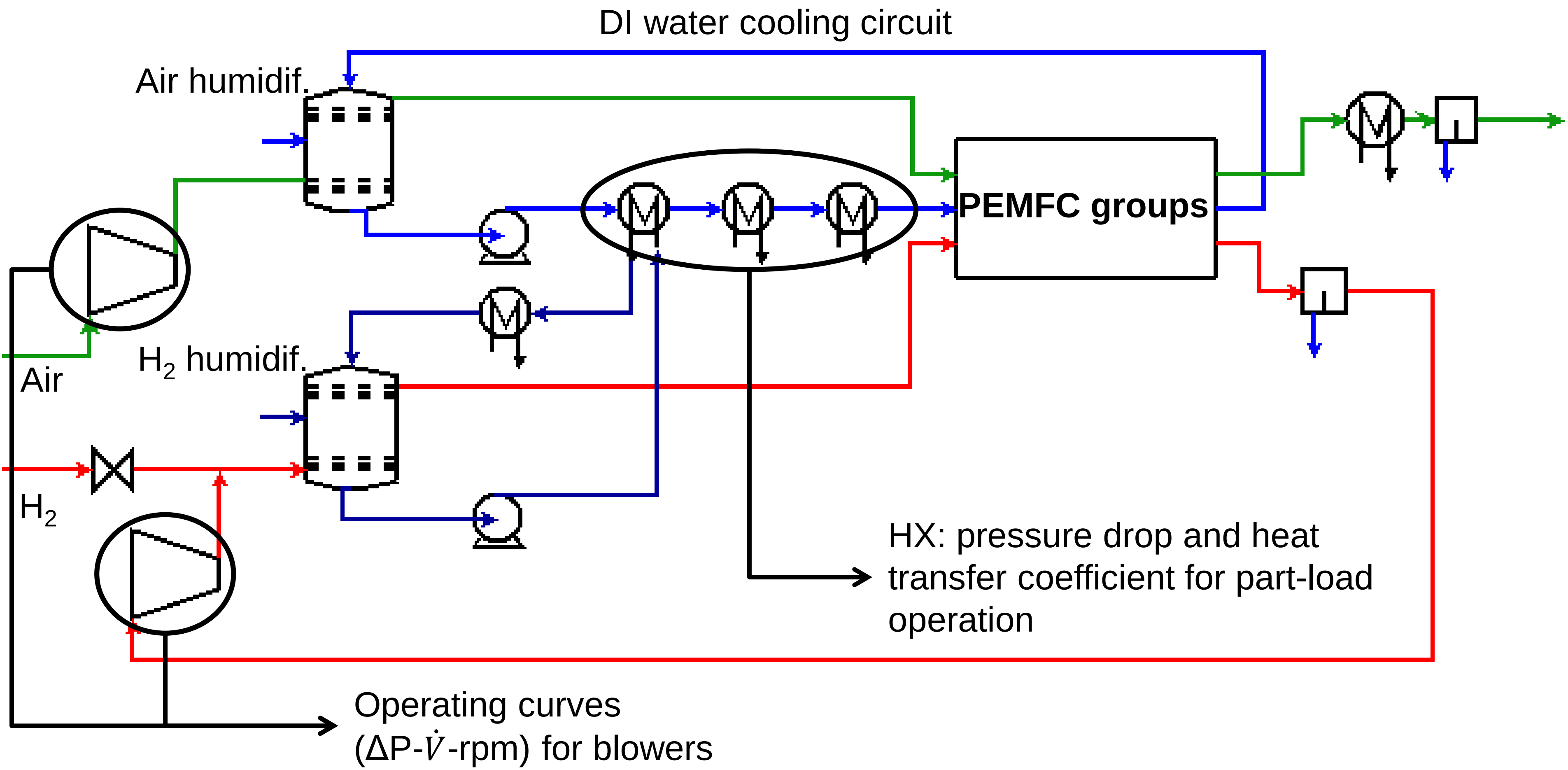
- high electricity price
- issues with supply shortages
- large chlor-alkali plants market - ca. 180 plants

Scale-up based on previous experiences (Nedstack & MTSA)

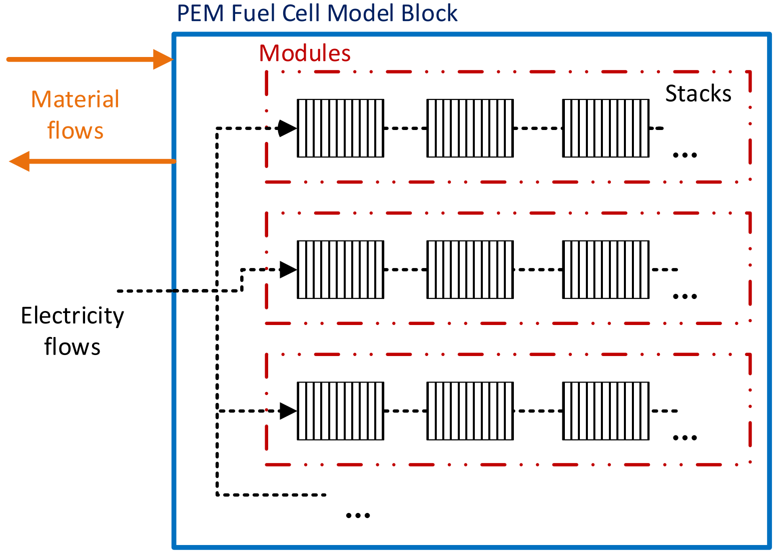
- **70 kW$_{el}$** PEM Power Plant at AkzoNobel (Delfzijl, NL, 2007)
- **1 MW$_{el}$** PEM Power Plant at Solvay (Antwerp, BE, 2011)

Plant Layout

Model implemented in Aspen Plus, with custom models, for full- and part-load analysis

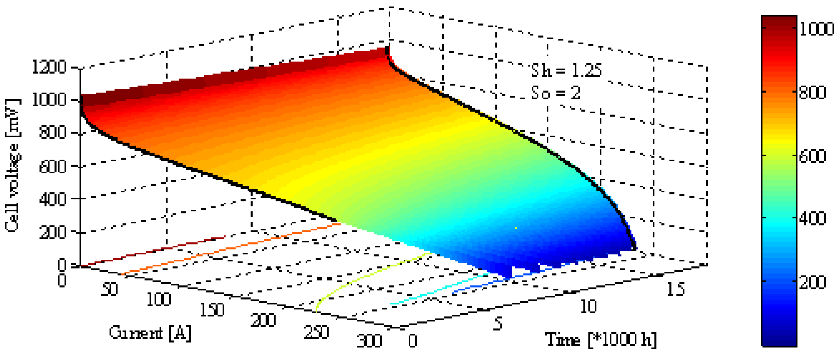


PEM FUEL CELL MODEL



Lumped model developed in Aspen Custom Modeler, for integration with the balance of plant is Aspen Plus

Reflects the architecture of the plant:
Cells x 75 = Stack
Stacks x 14= Module
Modules x 4 = Group
Groups x 6 = 2 MW power plant



Empirical formulation of the i-V curve, validated against experimental data
Considers reactants stoichiometry (x_{H2}, x_{O2}), exchange and limit current density (i_0, i_L), linear long-period voltage decay (t_{BoL}-t_{EoL})
Neglects T and RH effects: stacks at constant T and RH thanks to the cooling water circuit and humidifiers

$$V(i, x_{H2}, x_{O2}) = \left[A + B\ln\left(\frac{x_{H2}}{x_{H2,st}}\right) + C\ln\left(\frac{x_{O2}}{x_{O2,st}}\right) + Di + E\ln\left(\frac{i}{i_0} + 1\right) + F\ln\left(1 - \frac{i}{i_L}\right)\right] - G\ t(t_{BoL}, t_{EoL})$$

PLANT OPERATION

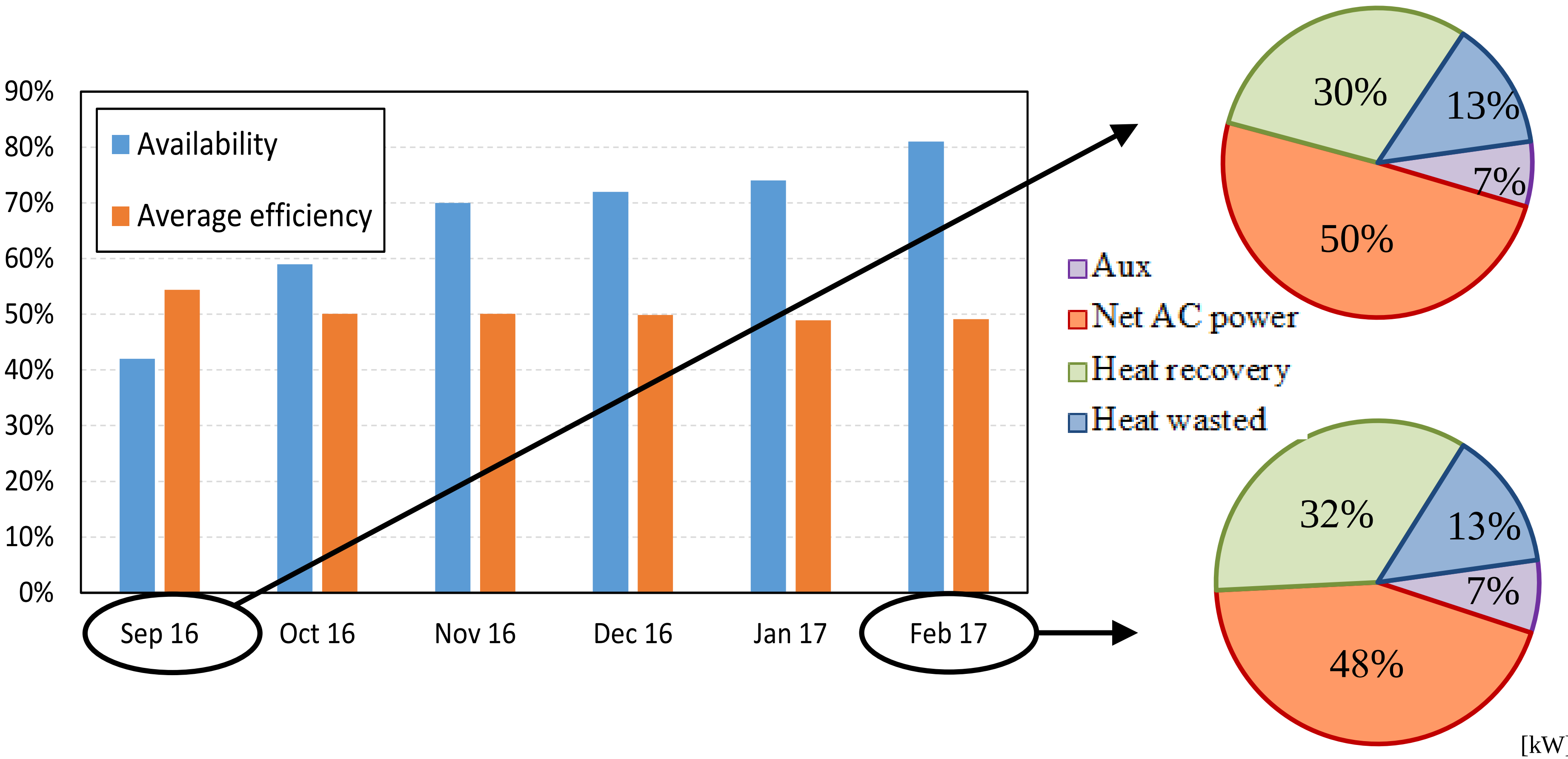
Construction and shipment of the plant from MTSA factory (NL) to Ynnovate Ltd in Yingkou, Liaoning province, China

https://www.youtube.com/watch?v=W8QE8iEXAyM

Opening ceremony on 14 October 2016 at plant location

Almost 10 months of plant operation: **data analysis**

DATA ANALYSIS: FIRST MONTHS OF OPERATION

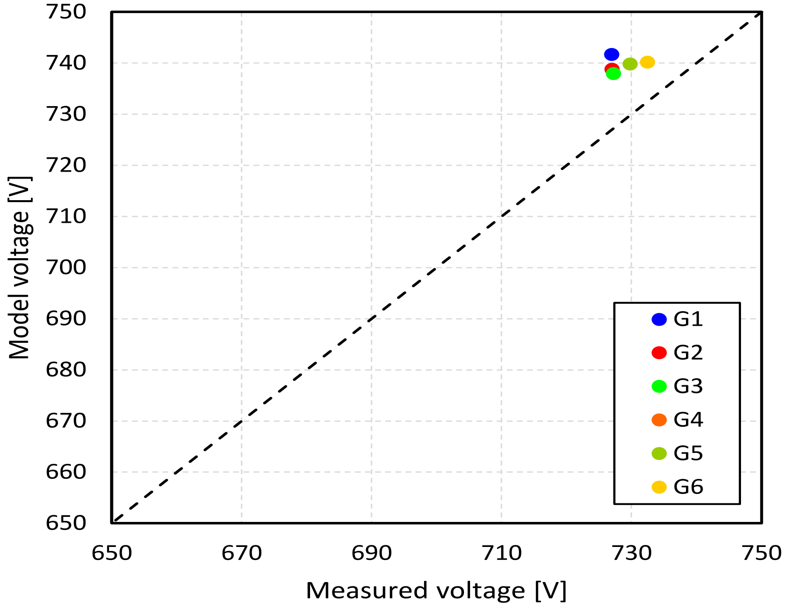


- Availability is increasing: main reason of low availability is **H_2 supply shortage** (and initial G4 inverter failure, now all the groups are available)
- **Net AC electric efficiency fulfills the 50% target** of the project, but decreases over time

DEMCOPEM 2MW

The complete PEMFC **power plant model is compared with field data**

Voltage deviation at plant start-up



Property	Model-Measurements deviation [%]			
Date	15 Sep 16	19 Sep 16	19 Sep 16	13 Oct 16
Active groups	5/6	4/6	3/6	5/6
Current [A]	-1.8%	-3.4%	-6.3%	-6%
Voltage [V]	+1.8%	+3.4%	+6.7%	+6.3%
Auxiliaries power [kW]	-1.2%	+9.7%	+8.9%	+6%
Coolant flowrate [m^3/h]	-0.6%	-0.5%	-0%	+0.1%
Stack temp. [°C]	-1.3%	-1.4%	-1.1%	-2.6%

Very good agreement at Beginning of Life;
Poor agreement after 1 month of operation mainly due to change in operating conditions and decay: additional calibration performed.

Conclusions & Outlook

- Simulations of DEMCOPEM 2 MW power plant with a specific plant and PEMFC models
- The model is compared with field data: observed voltage overestimation by the model because does not account for reversible decay
- The plant fulfils the target net electric efficiency (50%) at Beginning of Life
- Plant operation was not continuous mainly because hydrogen shortage
- Voltage decay is observed in field conditions:
  - Reversible decay: fully recovered after corrective actions
  - Irreversible decay: calculation procedure under development

Next steps:

- Simulations: refine PEMFC models; continue data analysis
- Plant: implemement strategies to limit the voltage decay

Thank you for your attention!

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