A3-Falcon: Advanced FC Analysis, Diagnostics and its Application

A3PS Conference: Eco-Mobility 2014

Sean J. Ashton

Intelligent Energy

- **International power technology company** with over 350 people worldwide
- Commercialising our **leading fuel cell technologies** with global business partners
- Substantial and growing intellectual property portfolio of **over 350 patents granted** and **550 pending**
- Established in 2001, but with a **history of over 25 years fuel cell innovation**
- Headquarters and principal facility in Loughborough, **UK** with operations in **India** and **Japan** and a commercial office in Silicon Valley, **USA**

First manned fuel cell aircraft

First purpose built fuel cell motorbike

First fully road approved fuel cell scooter

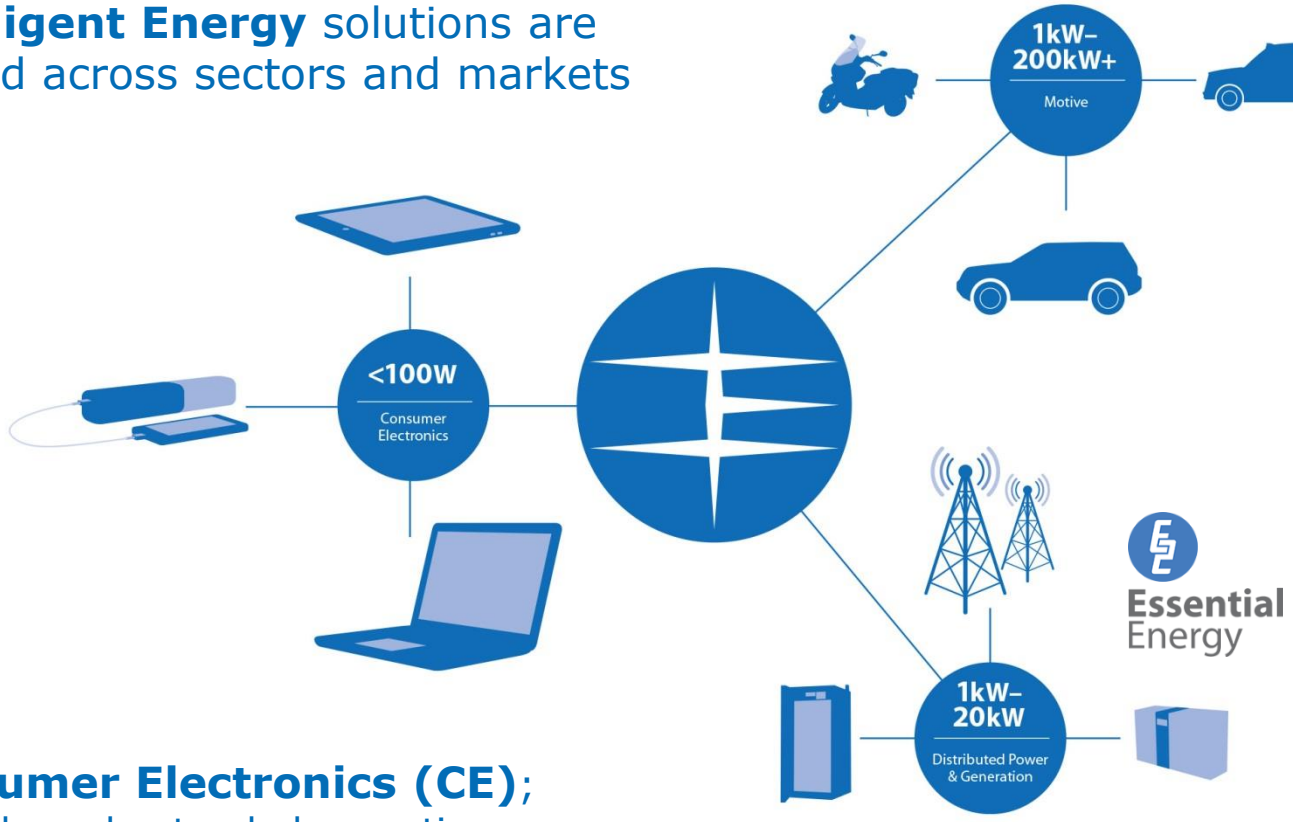
First PEM fuel cell black cab

www.intelligent-energy.com

Commercial Application Across Sectors

Motive Power; Two-wheeled vehicles, automotive, commercial vehicles

Intelligent Energy solutions are applied across sectors and markets



Consumer Electronics (CE);
Portable and extended operating power

Distributed Power and Generation (DP&G); CHP, backup and emergency power

www.intelligent-energy.com

Automotive Air-Cooled Fuel Cell Power Generation Systems

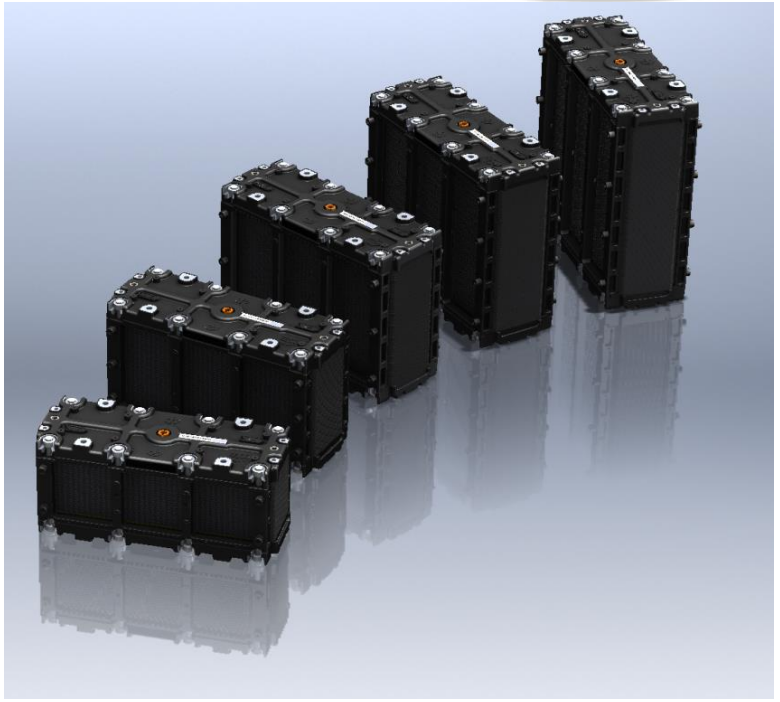
Gen4 Fuel Cell System overview:

- NET power output:
  4 kW (continuous)
- Storage ambient temperature:
  -40 to +85 °C
- Operating ambient temperature (inlet air temperature):
  -10 to +45 °C
- System net electrical efficiency:
  > 50 %
- Vibration:
  5 g x, y, z (or any combination)
- Shock:
  half sine wave 50 g/ 6ms
- System weight:
  < 20 kg

Air-Cooled Open-Cathode PEM Fuel Cell

Operating Principles:

- Open cathode (ambient air)
- Oxidant/coolant air provided by fan
- No external humidification
- High fuel efficiency (**> 99 %**)
- Simple system architecture
- Easily scalable:



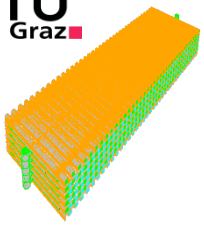
Automotive Gen4 Stack Parameters:

- Power Density of **0.96** kW/ L
- Specific Power of **0.75** kW/ kg

Advanced 3D Fuel cell AnaLysis and CONdition diagnostics – A3FALCON

AVL

TU Graz



- CFD Modelling
- Advanced Impedance Analysis
- THDA

a3plus

S++ SIMULATION SERVICES

- Spatial Measurement Hardware (I, V, Temp.)
- CurrentVIEW
- Z-Scan

Spatial Analysis of Fuel Cell Operation

Parallel Measurement & CFD Modelling

Improved Fuel Cell Operating Strategies

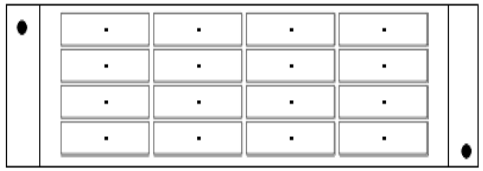
UCL

Intelligent Energy™

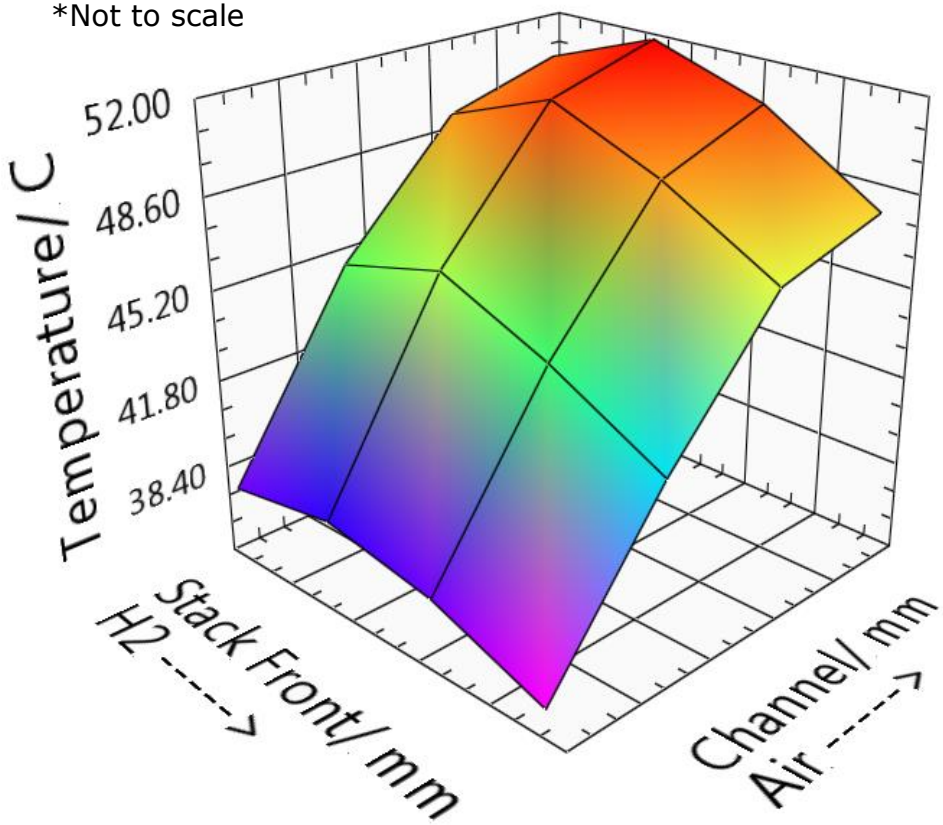
- Proven Fuel Cell Technology
- Fuel Cell Expertise
- Measurement Capabilities

www.intelligent-energy.com

Air Cooled Open-Cathode PEMFC Temperature Distribution

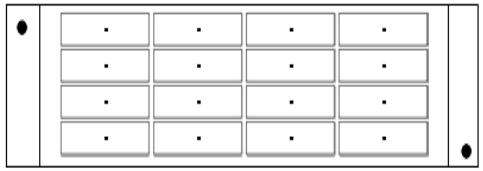


*Not to scale

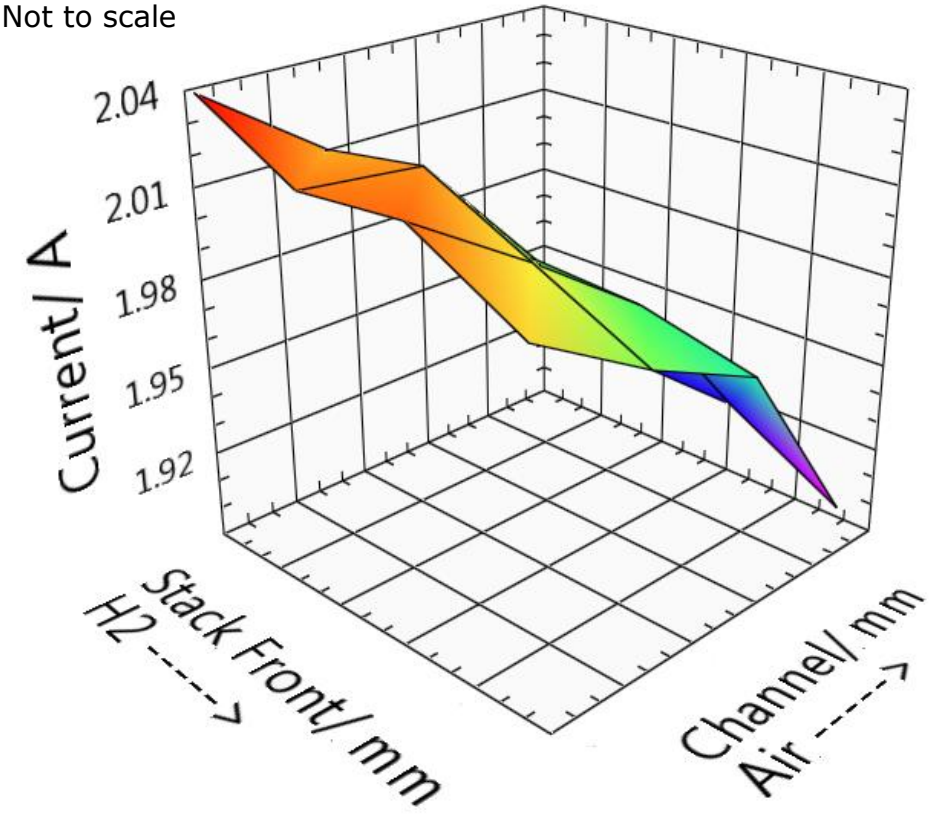


- Temperature distribution determined by air-coolant flow

Air Cooled Open-Cathode PEMFC Current Distribution



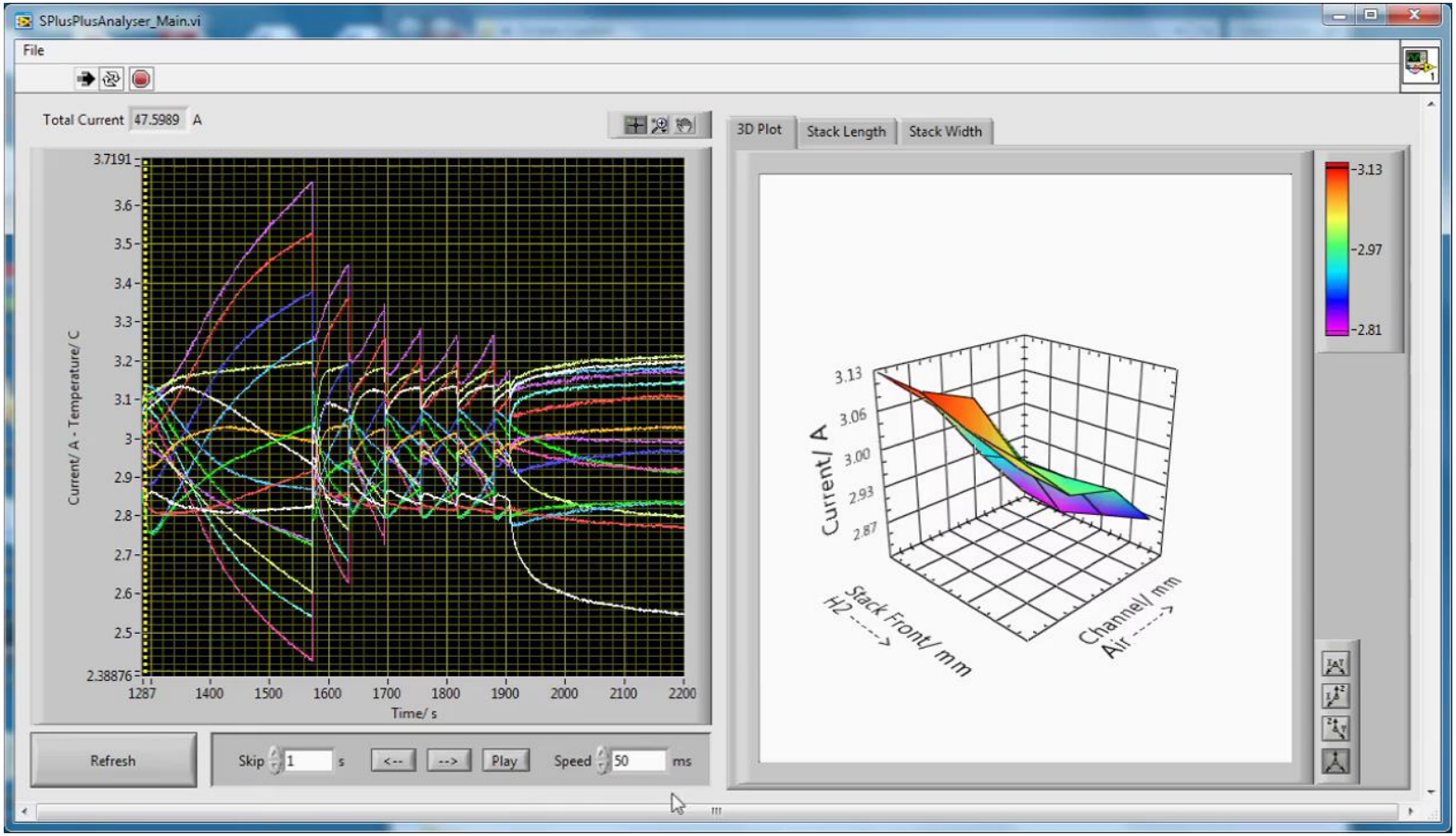
*Not to scale



- Cooler regions achieve highest current densities

Fuel Cells are Dynamic…

Example: Dead-Ended Anode Operation



*Embedded Video

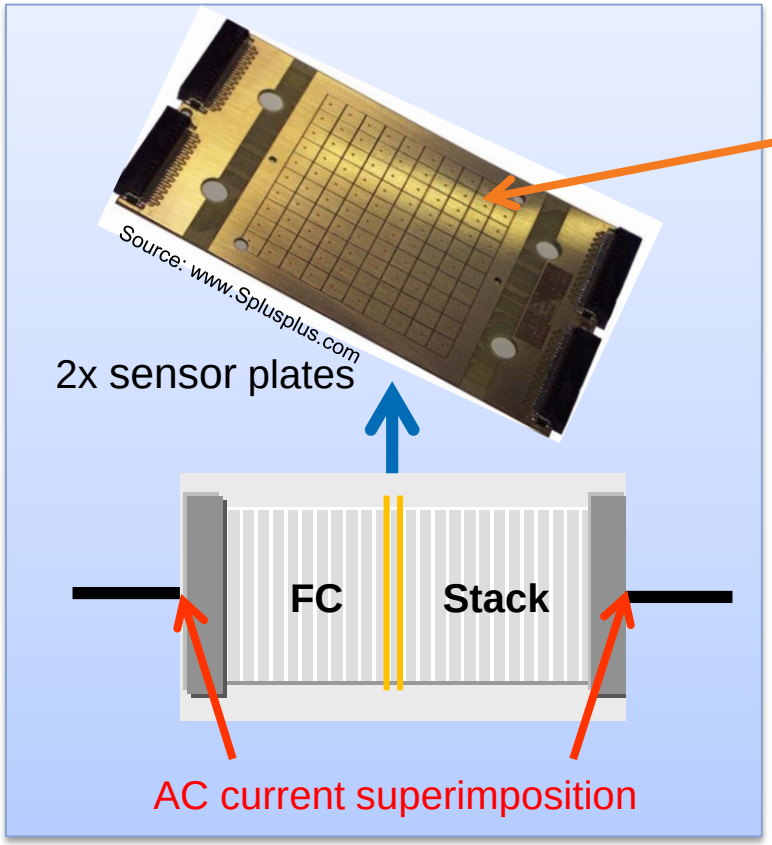
Related Electrochemical Impedance Spectroscopy (EIS) Study: **"Dead-ended anode polymer electrolyte fuel cell stack operation investigated using electrochemical impedance spectroscopy, off-gas analysis and thermal imaging"** Quentin Meyer, Sean Ashton, Oliver Curnick, Tobias Reisch, Paul Adcock, Krisztian Ronaszegi, James B. Robinson, Daniel J.L. Brett

www.intelligent-energy.com

How can we diagnose critical operating conditions? & where?

AVL THDA - New Approach: Segmented THDA

Segmented sensor plates between cells



Results for each segment

voltage, current, temperature

signal analysis

diagnostic algorithms

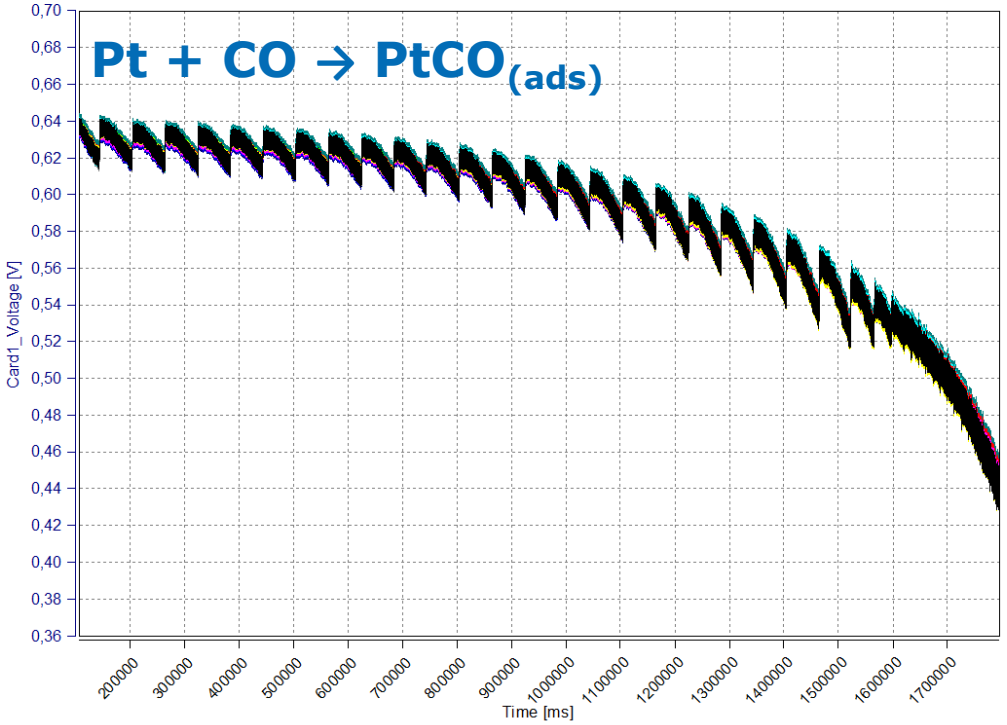
De-hydration

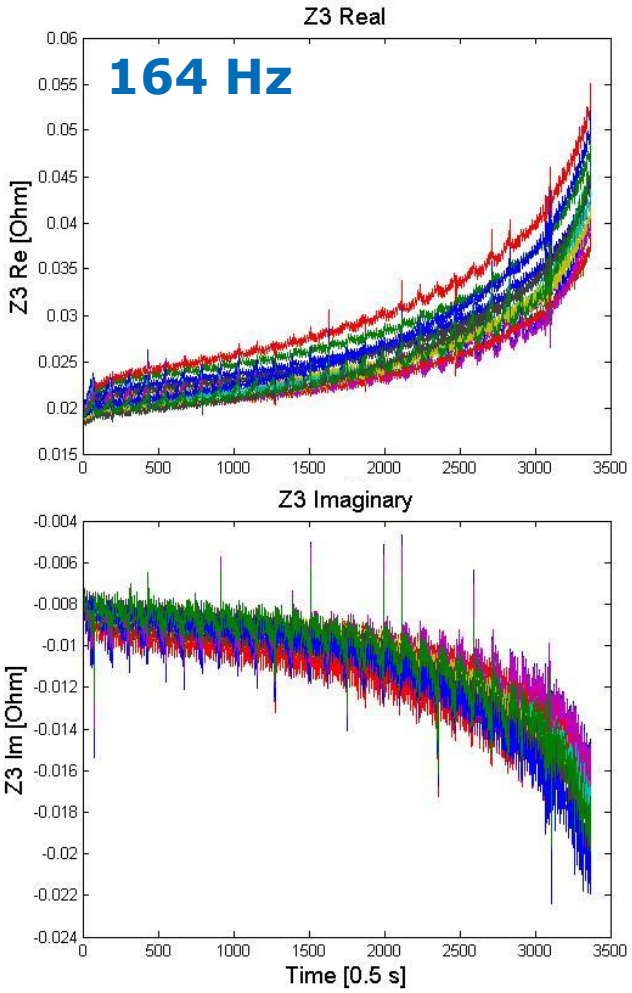
fuel/oxidant starvation

flooding

for each segment

Segment Impedance Example: CO Poisoning of Fuel Cell Anode

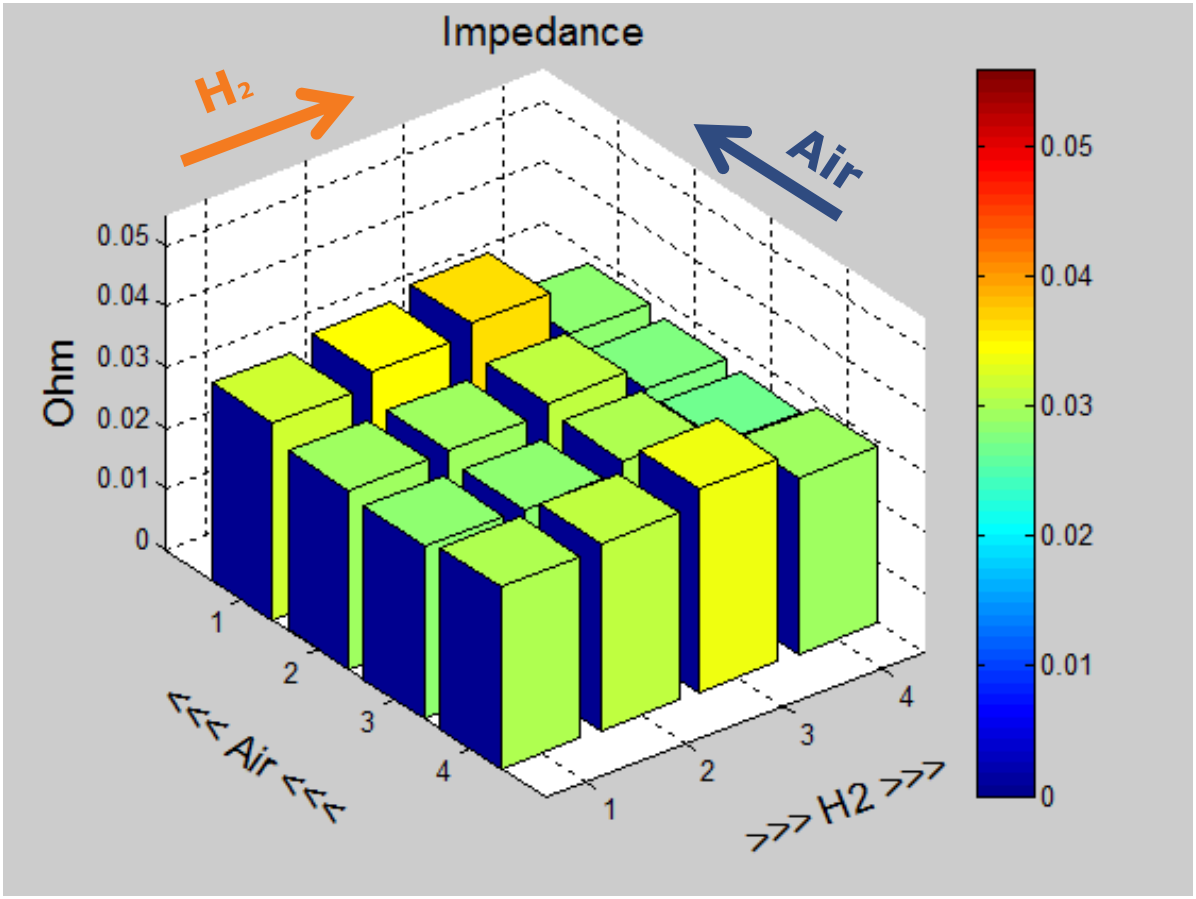




- **THDA Test Conditions**
  - AC Frequencies: 3Hz, 13Hz, 164Hz & 1000Hz
  - Current: 45 A
  - 10 ppm CO in Hydrogen

- **Test setup successfully resolves each segment's voltage and impedance**

Visualization of impedance (164Hz) change during CO poisoning of anode



*Impedance data provided by Katharina Renner & René Vötter, AVL

- First attempts suggests CO Poisoning does not generate THD signal...

Summary

- **Conclusions**
  - Spatial current and temperature mapping tools are useful toward better understanding fuel cell processes
  - Temperature and current distribution data crucial to support fuel cell modelling - but current, voltage and temperature alone is not enough
  - Segmented spectroscopy show clear changes in impedance but has no apparent impact on THD signal – more analysis needed

- **Outlook**
  - Combine current, voltage and temperature mapping tools with EIS
  - Progress work on spatial THDA algorithms to study dynamics and improve fuel cell control strategies

Ultimately use greater understanding and improved modelling tools to enhance fuel cell design, control systems and operating strategies