AVL PROTON EXCHANGE MEMBRANE FUEL CELL SYSTEM (AVL PEM FC SYSTEM)

Advanced fuel cell system for electric vehicles

MARKET & CUSTOMER CHALLENGES
- Zero-emission and complete decarbonization of the transport sector
- Electric vehicles with a long driving range (> 700 km) and a short refilling time (few minutes)
- Electrification of long-haul and commercial vehicles
- Efficient electric powertrain that provides high power and energy density
- Reduced battery size/cost in electric vehicles with increased driving range
- Innovative thermal management of PEM FC system and FC vehicle powertrains
- Commercially viable PEM FC vehicles

THE AVL SOLUTION
The AVL PEM fuel cell system development includes:
- Simulation tools from cell level to stack and vehicle level
- Vehicle concept studies
- PEM system development, including components and subsystems
- Hardware-in-the-loop calibration methodology
- Diagnostic-based control and FCCU calibration
- Thermal management
- E-drive and e-storage design and engineering
- Advanced testbeds for cell, stack, fuel cell system, powertrain, vehicle and dynos
- Vehicle conversion, packaging and integration
- AVL IP control system
- A customized fuel cell prototype for every concept car
- Benchmarking of fuel cell vehicles
AVL SERVICES IN DETAIL
• AVL advanced simulation tools for proficient PEM FC cell and stack design based on electrochemical fundamentals
• Customer-specific PEM FC system development including vehicle concept and drivability studies
• PEM FC system design assessment to maximize power density and efficiency of electric powertrains
• Development of PEM FC Balance-of-Plant components (e.g. injector/ejector unit)
• Hardware-in-the-Loop calibration of PEM FC systems, subsystems and Balance-of-Plant components (e.g. anode recirculation, compressor, system controls)
• Thermal management design for PEM FC systems and FC vehicle powertrains
• Build-up of PEM FC systems based on customer packaging requirements
• Comprehensive testing of PEM FC stacks, systems and Balance-of-Plant components
• Verification and validation of PEM FC system operation (up to 160 kW) under various environmental conditions (−40 to +85 °C) on AVL FC testbeds
• Operating strategy & control software development with integrated AVL THDA™ diagnosis methodology for optimized PEM FC system operation
• Non-invasive State-of-Health observation including detection and differentiation of diverse fuel cell failure modes during operation
• Power electronics, e-drive and e-storage engineering and development for powerful and efficient electric powertrains
• Vehicle conversion and prototype vehicle development for PEM FC system and powertrain integration

THE ADDED VALUE
• More than 15 years of experience in fuel cell engineering
• Execution of more than a 100 customer projects with automotive/non-automotive OEMs and Tier 1/2
• Customer-specific definition of fuel cell-based e-drive architectures, vehicle packaging and build
• Prediction of vehicle performance via model-based development to save development time and cost
• Customer-oriented fuel cell system and vehicle controls, including operating strategies and software development
• Detailed system and vehicle benchmarking as the basis for recommendation on system layout, cost, etc.
• Excellent supplier network for fuel cell stack, hydrogen tank and Balance-of-Plant components
• Detection and differentiation of failure modes during fuel cell operation thanks to new AVL diagnostic-based control device (AVL THDA™)
• Integration of diagnostic-based fuel cell control into the vehicle’s control unit and power electronics without added hardware costs
• Continuous support during commercialization of fuel cell vehicles based on a wide IPR portfolio

REFERENCES
• Customer-specific development of PEM FC systems from prototypes to SOP & system integration projects in passenger cars, trucks and buses
• Prototype and demonstration project of PEM FC systems with various automotive/non-automotive OEMs and Tier 1/2
• Fuel cell stack diagnostic-based control projects with 8 different OEMs by using AVL THDA™
• Deep-dive benchmarking of the Toyota Mirai fuel cell car

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AVL SOLID OXIDE FUEL CELL COMBINED HEAT AND POWER (AVL SOFC CHP)

Conversion of any hydrocarbon-based fuel or gas into electricity at highest efficiency

MARKET & CUSTOMER CHALLENGES

• Power generating technology to meet global CO₂ reduction targets and noise emission legislation limits
• Easily deployable and robust power generation technology for a wide variety of conventional and renewable fuels (including fuel cleaning and fuel processing)
• High electricity-to-heat ratio of 2:3 to enable > 8000 full load operating hours
• Provision of modular design for a wide power range from kW to MW
• Possibility of water-neutral operation to avoid expensive water treatment and supply
• Remote system control possible (no onsite operating staff required)
• High electrical efficiencies and reduced service effort for lowest total cost of ownership

THE AVL SOLUTION

AVL covers the complete development process of SOFC CHP & combined cooling, heating and power (CCHP) – from system simulation, component development to prototype manufacturing and testing:

• Power range: kW – MW
• Fuels: conventional (natural gas, diesel, LPG, ethanol, methanol, etc.) & biofuels (biogas, biomethane, synthetic diesel, etc.) for CO₂-neutral operation
• Electrical efficiency: 60 % plus
• Total efficiency: 90–95 % (by usage of the heat)
• Low operating expenditure (due to low fuel consumption)
• Low total cost of ownership, maintenance & service
• Practically emission-free (zero NOₓ, SOₓ, CO, PM)
• Very low noise compared to conventional CHPs
• Target lifetime up to 80,000 h
AVL SERVICES IN DETAIL
- Comprehensive process simulation environment for SOFC stacks and systems
- CFD and FE simulation of SOFC systems and balance-of-plant components
- FMEA
- Development of balance-of-plant components (e.g., compressor, reformer, media supply, burners)
- Supplier screenings (e.g., heat exchanger, afterburner)
- Stack technology benchmarking
- Design of complete SOFC systems including packaging studies
- Testing of SOFC systems, stacks, Balance-of-Plant & components (e.g., compressor, reformer)
- Integration of SOFC systems
- Control algorithm development
- Testing and validation of SOFC systems
- Design-to-cost and design-to-manufacture development
- Small-scale series manufacturing
- Techno-economic analysis

AREAS OF APPLICATION
- Data Centers
- Multi Family Homes
- Telecom Stations
- Industry & Decentral Energy
- Hospitals
- Hotels

THE ADDED VALUE
- Efficient heat recovery thanks to high temperature exhaust gas heat (> 200 °C)
- System applicable for grid connection and/or island operation
- Scalable power output from a few kilowatt to multi megawatt applications
- Advanced simulation models for SOFC CHP system and components
- 15 years and more than 100 projects experience in fuel cell engineering
- Know-how out of more than 10 SOFC system development programs
- SOFC CHP with industry wide smallest package and unique performance
- Comprehensive SOFC-specific FMEA experience
- Fuel cell test center in the range of 1 – 20 kW
- Testing facility for containerized solutions up to 1000 kW
- Wide IPR portfolio to support industrialization of fuel cell products

REFERENCES
- > 5 kW SOFC CHP system development and concept studies for customers of the gas appliances industry
- > 200 kW SOFC system concept studies for power plant developer
- Design and build-up of large stack modules for large power generation manufacturer
- Stack benchmark studies

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AVL SOLID OXIDE FUEL CELL (SOFC) PORTABLE POWER GENERATION

MARKET & CUSTOMER CHALLENGES
• Power supply of vehicles & yachts while the main engine is turned off
• Environmentally friendly & portable power generator compatible with any type of fuel
• 30–50% lower fuel consumption compared to engine-based APUs
• Power generation with very low noise and no vibration
• Close to zero harmful emissions like CO, NO, and PM
• Reduced maintenance cost and extended lifetime

THE AVL SOLUTION
AVL develops SOFC systems for portable power generation with two applications. One is the SOFC Range extender (SOFC REX) / battery charger, the second the SOFC Auxiliary power unit (SOFC APU).
• Power range: 5-20 kW
• Efficiency of 35–50% (depending on the fuel type)
• Conventional fuels (diesel, gasoline, LPG, CNG, ethanol, methanol and etc.) and biofuels (biogas, biomethane, synthetic diesel, etc.)
• Practically emission-free
• Vibration-free and very low noise ~ 50 dB(A)
• Low thermal signature and maintenance cost
• Lifetime up to 8,000 h
• Ambient conditions –30 – 50 °C

Comprehensive experience leading to outstanding solutions
AVL SERVICES IN DETAIL
- Comprehensive simulation environment for SOFC stacks
- CFD and FE simulation of SOFC systems and balance-of-plant (BoP) components
- FMEA
- Development of BoP components (e.g. compressor, reformer, media supply, burners)
- Design of the complete SOFC systems including packaging studies
- Testing and validation of SOFC systems, stacks, BoP & components (e.g. compressor, reformer)
- Integration of SOFC systems
- Stack technology benchmarking
- Control algorithm development
- Design-to-cost and design-to-manufacture development
- Small-scale series manufacturing

AREAS OF APPLICATION
- Range extender/battery charger for Battery Electric Vehicles (passenger cars, low & medium duty commercial vehicles and buses)
- APU for heavy-duty trucks while the main engine is turned off
- APU for yacht & special purpose vehicles
- Wherever a portable power generation is needed

THE ADDED VALUE
- 15 years of experience in fuel cell engineering
- Execution of more than 100 projects with automotive/non-automotive OEMs and Tier 1/2
- Strong IPR portfolio to support industrialization of fuel cell products
- SOFC REX & SOFC APU with industry-wide smallest package and unique performance
- Reducing the start up time of SOFC system with new cell technology
- Advanced simulation models for SOFC
- Equipped SOFC test stations
- Industry network and benchmark experience with all leading SOFC stack suppliers

SELECTED REFERENCES
- SOFC APU integration projects in trucks and special purpose vehicles
- Development of SOFC REX system (as range extender/battery charger for battery electric vehicles) to customer specifications from prototypes to SOP
- Development partner in various mobile SOFC projects (automotive/non-automotive OEMs and Tier 1/2)
- Field and demonstration tests of AVL SOFC REX & SOFC APU

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AVL TOTAL HARMONIC DISTORTION ANALYSIS (AVL THDA™)

MARKET & CUSTOMER CHALLENGES
- Stack friendly operation at max fuel utilization
- Increased reliability of stack operation
- Online diagnosis of fuel cell stacks
- Operation feedback for control unit
- Early detection of faults
- Replacement of unreliable CVM
- Cost optimization of fuel cell monitoring
- Estimation of State of Health (lifetime prognosis)
- Discover enhancement potentials on stack level
- PEMFC: Optimized water management
- SOFC: Prevention of carbon deposition

THE AVL SOLUTION
AVL THDA™ is a unique patented technology for diagnosis of fuel cell stacks:
- is both a lab device & methodology for monitoring large stacks up to 500 V
- plug and play device for Fast-EIS of full stacks
- sinusoidal excitation currents can be applied on up to 5 frequencies simultaneously
- full integration in your test station via CAN interface
- capable of being integrated as software in vehicle control unit
- online monitoring of state of operation (SoO) for fuel cell stacks
- SoO-indicators for PEMFC:
  1) Low media, 2) Dry out, 3) Liquid water
- frequency range optimized for PEMFC
- enables optimized operation of fuel cell with minimal instrumentation effort
AVL SERVICES IN DETAIL
- Embedding of AVL THDA™ methodology in to your fuel cell application
- Integration support of THDA into your test station
- THDA work shops at customer site
- Customized THDA projects (e.g. CVM replacement)
- Testing of DC/DC converters with respect to its THDA capabilities
- THDA data analysis tools (THDA™ toolbox available, can be modified and extended to your needs)
- Design of low noise high voltage AC-probes (certified for high voltage applications)
- Development of THDA ready DC/DC converters for automotive application
- Buildup of high voltage AC-digitizers (sampling bandwidth up to 1 MHz, AD-resolution up to 24bit, common mode voltage up to 500 V)
- THDA ready load banks for full stacks up to 250 kWel
- Analysis of your THDA test data

THE ADDED VALUE
- More than 15 years of experience in fuel cell engineering
- Execution of more than 100 customer projects with automotive/non-automotive OEMs and Tier 1/2
- A novel diagnostic-based control device for detection and differentiation of failure modes during fuel cell operation
- Integration of diagnostic-based control fuel cell monitoring into the vehicle control unit and the power electronics of the vehicle without added hardware costs
- Advanced tool for experts for better understanding of the current status of the stack as well as the interaction between power electronics and stack
- Hydrogen cross over in PEM electrolysis
- Replacement of unreliable CVM in PEMFC or carbon deposition in SOFC
- Continuous EIS on large stacks
- Capable of being fully integrated into different test bed environments via CAN-protocol

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