Evaluation of different system configurations for a heavy duty PEM fuel cell system model

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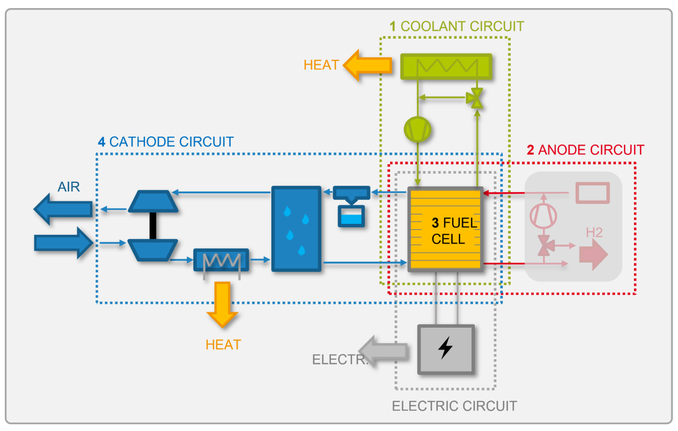
Introduction

A fuel cell system for heavy duty applications was modeled and simulated with different BoP and system configurations to evaluate and compare total system efficiency. Key components were validated by in-house measurements and public data of suppliers. Validation took place in terms of pressure drops, heat transfer rates, stack polarization curves and humidification performance. Different air circuit configurations were modeled to evaluate reduction potentials for the compressor power consumption. Stationary simulations at different operating points as well as dynamic drive cycle simulations were used for evaluating the overall efficiency in a wide operating range.

Modeling Approach

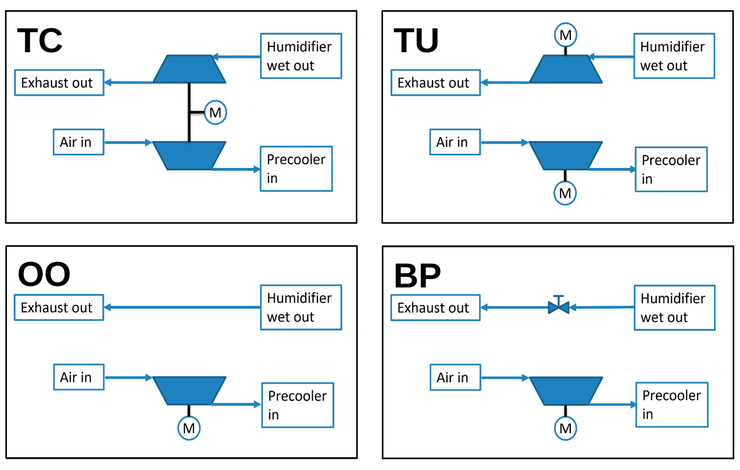
- AVL Cruise™M Software was used
- Focus on cathode and cooling circuit
- In-house measurements were used to validate the stack model
- Anode circuit modeled in a simplified way



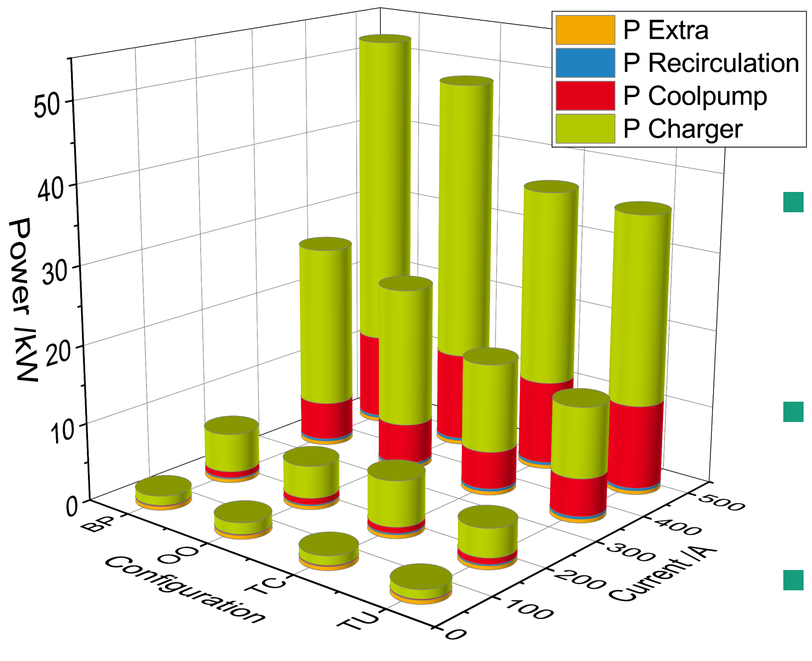
System Configurations

Four configurations evaluated:

- Turbocharger (**TC**): Compressor and Turbine coupled on same shaft
- Compressor and Turbine uncoupled **(TU)**
- Compressor and open outlet (**OO**)
- Compressor and Back Pressure Regulator (**BP**)



Stationary Comparison of BoP Power Consumption

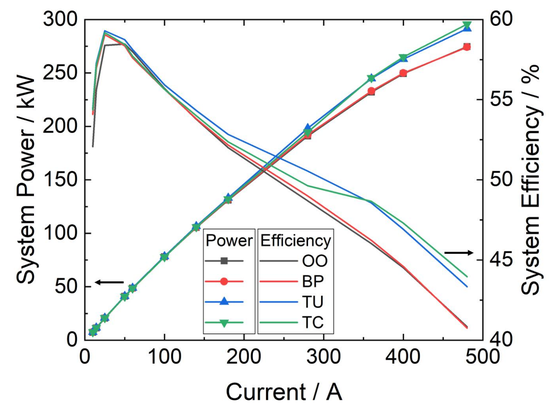


BoP power consumption for all four configurations at different fuel cell operating currents

- TU and TC show large potential in reduction of consumed power at medium and high currents
- OO shows a slightly lower power consumption compared to BP at all currents
- At low currents, no configuration has a significant advantage

Stationary Comparison of Efficiency and Power

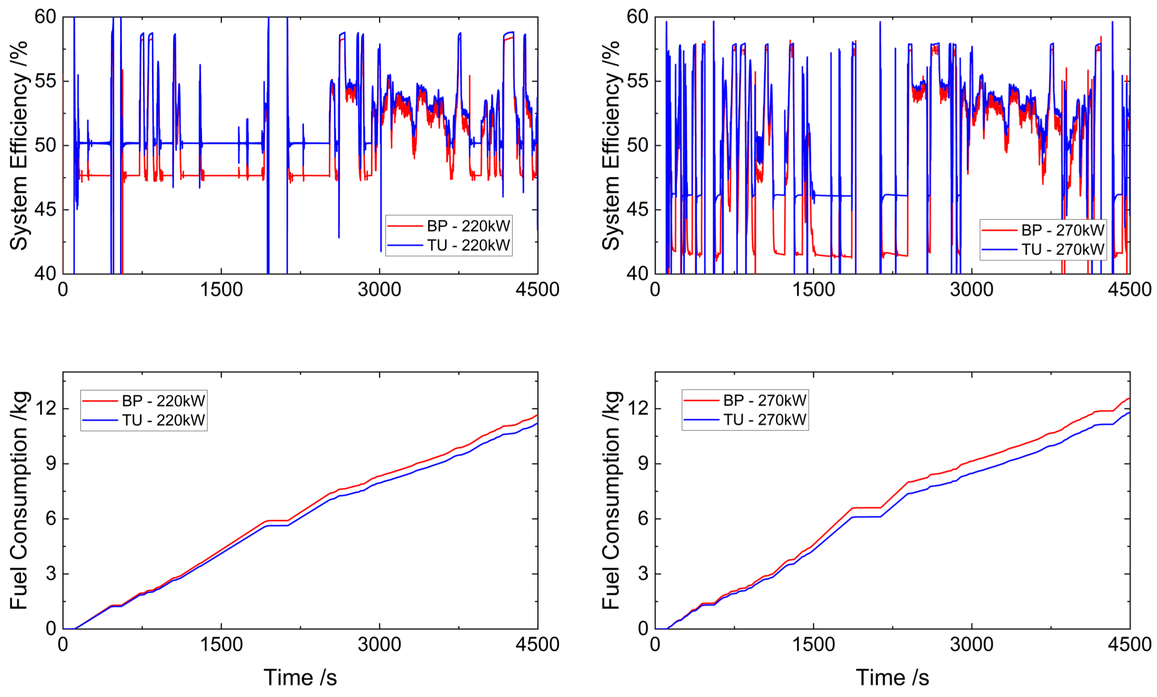
- System power and efficiency show two groups of configurations: TC and TU are more efficient at high currents than BP and OO
- TU has the best power at a wide current range
- TC has the best power at highest currents
- OO does not show an advantage in system power and efficiency



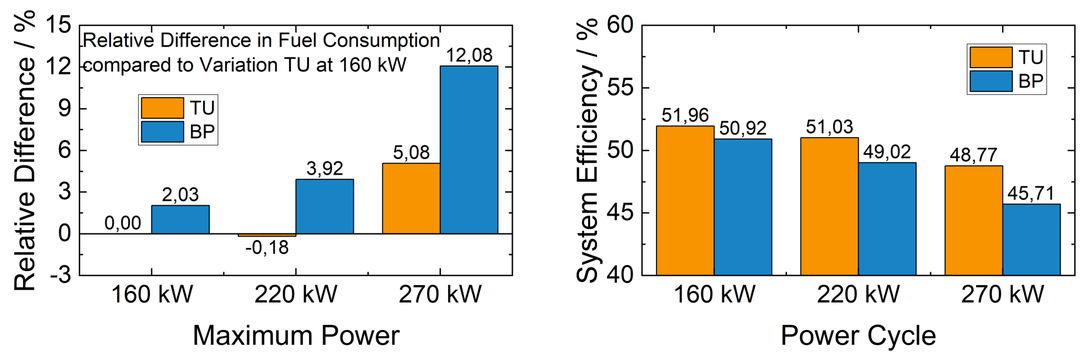
System Power and Efficiency for all four configurations at different operating currents

Dynamic Drive Cycles

At dynamic simulations, the configurations BP and TU are compared to each other because they represent the state of the art and the turbine-efficiency optimized cases.



Comparison of fuel consumption and system efficiency for a dynamic drive cycle (VECTO Long Haul) with two different hybridization levels for two configurations BP and TU



Relative difference in fuel consumption and system efficiency for three hybridization levels and configurations BP and TU

- TU has a better efficiency and fuel consumption than BP in every load cycle
- The relative difference between both configurations increases with increasing power demand of the fuel cell system
- With a turbine a higher maximum cycle power with higher dynamics is possible at same fuel consumption as with lower maximum cycle power and lower dynamics

Different air circuit configurations have been analyzed. The energy saving potential of a turbine, especially at high load, has been proofed in stationary and dynamic applications.