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ALADIN II – Highly Efficient and Near-Zero Emission Micro Combined Heat and Power Plant

Recent energy policies smooth the way for future strategies that are partly based on various renewable energy sources, such as solar or wind. However, these sources are strongly dependent on environmental factors. In this context, decentralized power generation with combined heat-and-power (CHP) units becomes increasingly popular, as those units do not only maximize energy efficiency by providing heat and power as close as possible to the consuming household, but are also able to provide regulative power to the electricity distribution network. The research project "ALADIN II" deals with the development of a micro combined heat and power plant (mCHP) which not only provides a high electric efficiency, but simultaneously emits near-zero pollutant emissions.

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Goals

Vision

- Near-Zero Emissions
- High Electric Efficiency
- Fast Load Uptake
- Highly Efficient Waste Heat Utilization

Properties

- Fuel: Natural Gas (NG)
- Engine: 1-cylinder, 325ccm³
- Operation: Full load @ 3000 rpm
- Generator: Asynchronous (cos φ =0.93)

Research Foci

- Optimized Cold Start Strategies for
  1. Fast Plant Warm-Up
  2. Pollutant Emission Reduction
- Intelligent Operation Management
- Sophisticated Air/Fuel Ratio Control

Design

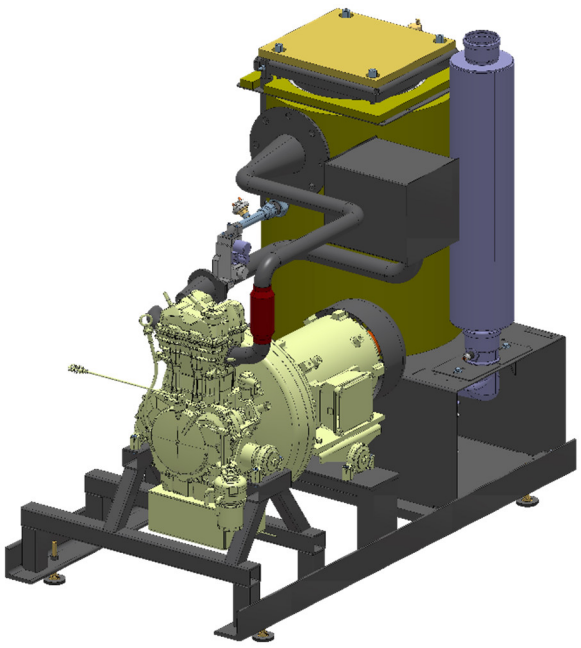

Fig. 1: Prototype Unit

Focus: Optimized Plant Warm-Up

By means of two integrated 3-way valves a dedicated control system regulates the heat transfer between two hydraulic circuits to accelerate the plant's warm-up. Compared to a standard layout with no specific measures for the warm-up procedure, the time in which the CHP operates without generating a thermal benefit is reduced by 50%.

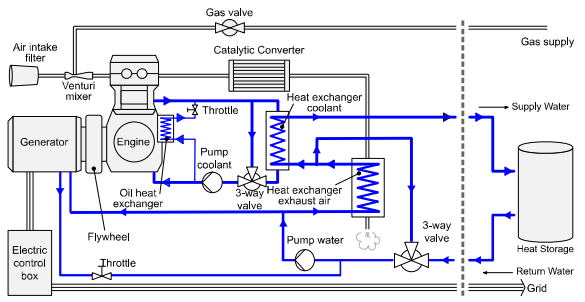

Fig. 2: Schematic Plant Representation

Focus: Cold Start Emission Reduction

An air/fuel ratio (AFR) control system regulates the gas mixture with focus on near-zero steady-state emissions. In addition, a second control system utilizes 1. the setpoint of this AFR-controller and 2. the engine's ignition timing to minimize the pollutant emissions during a cold start which are proven to make up for a large fraction of the total emissions during operation[1].

With these measures, the relevant pollutant emissions during a cold start operation procedure of ***t = 60min*** can even be kept below the regulatory limits that are effective for steady-state operation (Fig. 3).

The total hydrocarbon (THC) emissions, in this case almost entirely methane (CH_4) and therefore a greenhouse gas (GHG), are insignificant regarding their effect on global warming, compared to the CO_2-emissions due to sheer combustion of fuel (Fig. 4)

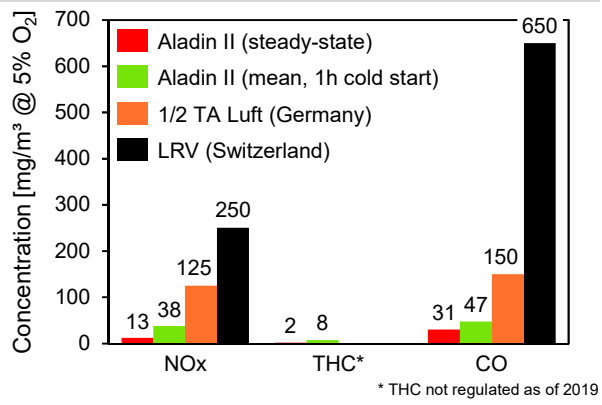

Fig. 3: Resulting pollutant emissions and legal limits (steady-state)

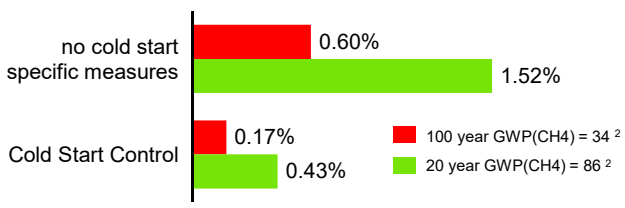

Fig. 4: GWP of CH_4 emissions during 1h cold start operation

Expected Impact

The results to date show that the integration of dedicated hardware (valves) and software solutions (control systems) can have far-reaching, positive effects on energy efficiency and pollutant emissions, if their use is targeted to the specific operating conditions of CHPs. The focus on cold start specific solutions offers great potential, as numerous components work with reduced performance in this transient phase (e.g. oil, pipings, heat exchangers, catalytic converter). For the Aladin II mCHP, the solutions lead to 50% faster generation of thermal energy, near-zero steady-state emissions and very low cold start emissions. The GWP of the remaining unburned hydrocarbon emissions is extremely low, i.e. the global warming effect stems almost entirely from the CO_2-emissions due to the combustion of fuel. The solutions can easily be adapted to CHPs of higher scaling levels. Future research on operational concepts of CHPs will integrate these solutions and is expected to lead to further benefits in terms of energy efficiency and pollutant emission reduction.

References

[1] Reiter, M.S. et al.,
The problem of cold starts:
A closer look at mobile source emissions levels
Transportation Research Part D: Transport and Environment
Volume 43 (2016), pp. 123-132

[2] Myhre, G. et al.,
Anthropogenic and natural radiative forcing
Cambridge University Press
Cambridge, UK, (2013), pp.659-740

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