Operational Flexibilities of micro Gas Turbines

Presentation presented at the *The Future of Micro Gas Turbines* Mini-symposium
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Operational Flexibility of Micro gas turbines

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The Future of Micro Gas Turbines
Mini-symposium
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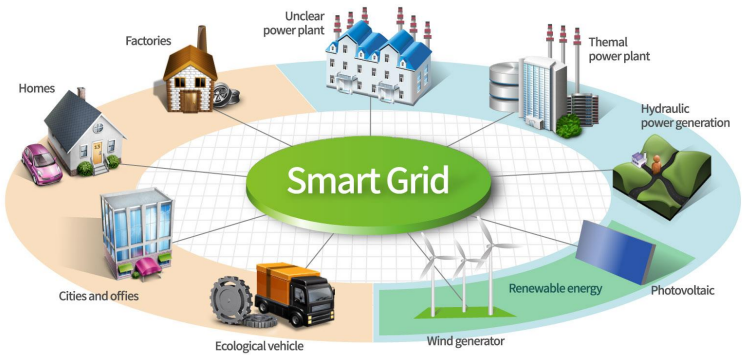
Micro Gas Turbines or mGTs have their place in future energy production.



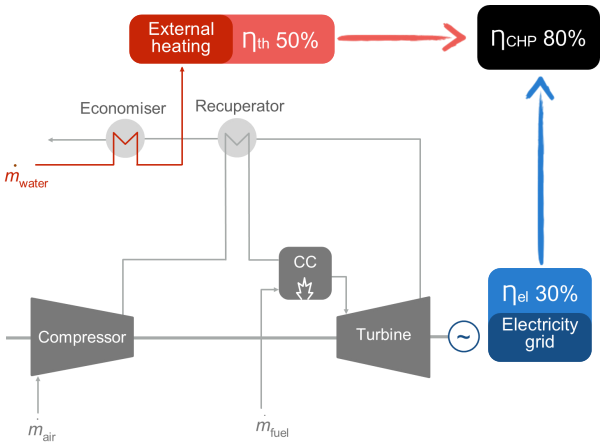
To get a place in the future energy production, the mGT needs to evolve.

The mGT has to become more efficient
- both at full and part load operation

The mGT has to become fully CO_2 neutral/negative
- by using biofuel/bio-energy
- by possible integrating capture

The mGT has to become MORE flexible
- flexible in terms of fuel
- flexible in terms of cycle layout
- flexible in terms of operation

Micro Gas Turbines (mGTs) have very high Combined Heat and Power (CHP) efficiencies

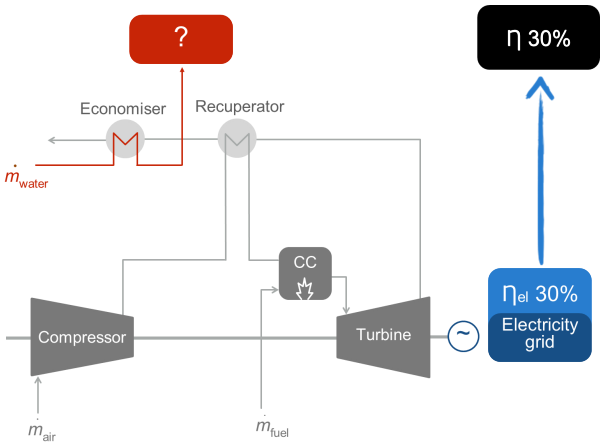


The flexible mGT needs to become more operational flexible

mGTs are already highly flexible
- for electricity/heat production separately,
- with similar full and part load efficiency
- but both productions are coupled.

mGTs are linked to real users with real demand curves.
- users have specific demands
- electricity and heat demands are not linked
- electricity is easier to handle than heat

If there is no use for the heat output,
the total efficiency is too low



Several options are available for waste heat recovery
to increase the operational flexibility.

Introduce mGT into a system with heat storage

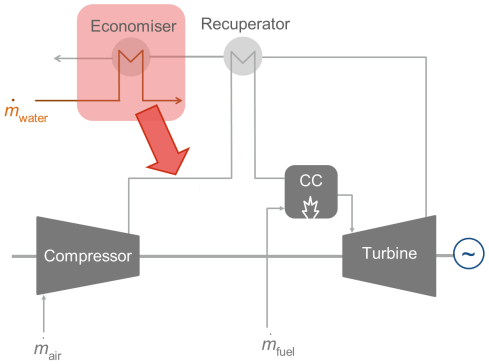
- short term storage is possible with current technology
- long term storage is still an issue

Link the mGT with a bottoming cycle

- large investment cost and even less operational flexibility

Re-introduce waste heat into the cycle through humidification

When heat demand is low…
the hot water is re-used in the mGT



Several options exist for waste heat recovery through water injection

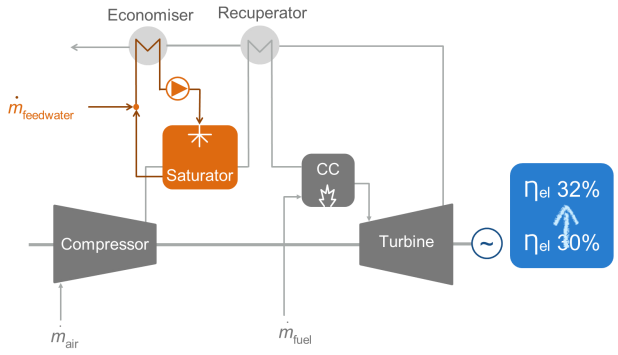
3 main categories

- steam injected cycles
- water injected cycles
- cycles with a saturation tower

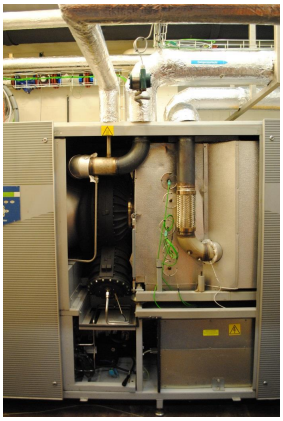
The micro Humid Air Turbine (mHAT) is the most promising cycle

- combines high efficiency with cycle simplicity
- possible to operate both dry and wet mode.

By humidifying the compressed air we increase the electrical efficiency



The mHAT concept was experimentally tested and validated in our test rig.



The mHAT concept was experimentally tested and validated in our test rig.

Recommendations for improved operational flexibility of mGTs using humidified cycles.

Turbo-machinery

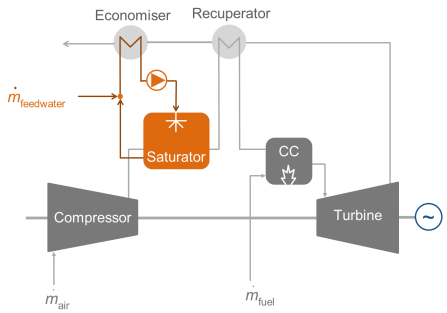
Cycle layout

Combustion

Recuperator

mGT turbo-machinery parts have favourable off-design behaviour

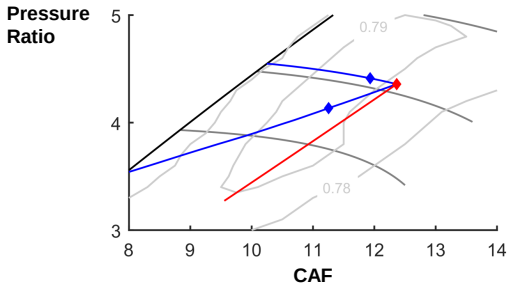
Mass imbalance due to water injection
forces on shaft are no longer balanced.



Experimental work shows no unstable behaviour.

mGT turbo-machinery parts have favourable off-design behaviour

Surge margin reduction due to turbine choking



Variable speed operation allows for larger surge margin.

mGT turbo-machinery parts have favourable off-design behaviour

Mass imbalance due to water injection

forces on shaft are no longer balanced.

experimental work shows no unstable behaviour.

Surge margin reduction due to turbine choking

variable speed operation leads allows for larger surge margin.

No need for redesign,
but cycle will benefit from higher efficiency

Recommendations for improved operational flexibility of mGTs using humidified cycles.

Turbo-machinery

Cycle layout

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Recuperator

The humidified cycles must remain simple, since this is the main advantage of mGTs.

Cycle must be simple

- main advantage of mGT is simplicity
- operation must not required skilled personnel.

Limited extra volume added

- possible turbo-machinery instabilities during load shifts.
- regulation problem: pressure vessel

Exclude mGTs from pressure regulation + better insight in dynamic behaviour

Recommendations for improved operational flexibility of mGTs using humidified cycles.

Turbo-machinery

Cycle layout

Combustion

Recuperator

Combustion stability is negatively affected by the

Water has an impact on combustion

- shift to higher equivalence ratio
- load shifts are very crucial (avoid flameout)

No need for new combustion chamber, but adapted control system.

- adjust control parameters based on water content.

What about combustion stability when going to high CO_2 content or alternative fuels?

Shift to more advanced combustion mode, like Flameless Combustion

Recommendations for improved operational flexibility of mGTs using humidified cycles.

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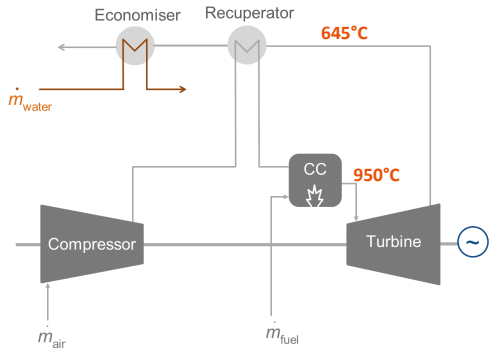
Recuperator

Higher quality recuperator materials are necessary to fully exploit the potential for humidification

Changing fluid properties leads to temperature mismatch



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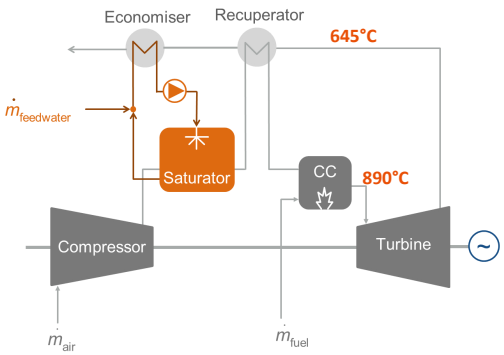

Higher quality recuperator materials are necessary to fully exploit the potential for humidification

Changing fluid properties leads to temperature mismatch

- For constant TOT, TIT is lower, leading to lower efficiency
- To increase TIT, new materials are necessary to protect the recuperator.

Humidification increases rapidly degradation of recuperator

- lifetime of the recuperator is reduced
- recuperator's lifetime determines file time of mGT.

The recuperator needs a possible redesign.

Humidified mGT cycles require larger recuperators

- increasing heat capacity and aftercooler effect allows for more heat recovery
- larger recuperator allows for higher efficiency

Modular design offers answer

- plug-and-play system, optimized for dry, wet or intermediate operation.

Recommendations for improved operational flexibility of mGTs using humidified cycles.

Turbo-machinery

Cycle layout

Combustion

Recuperator

Still potential to be unlocked.

BETTER PERFORMANCE EXPECTED WITH ADAPTED MGT FOR MHAT OPERATION LEADING TO MORE OPERATIONAL FLEXIBILITY

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