Flexible Power Generation – ETN Webinar Series – 4th Episode

PUMP-HEAT

Innovative concept to increase flexibility of combined cycle power plants and gas turbines

Tuesday, January 12, 2021 • 12:00am – 01:00 pm

Challenges for the integration of heat pumps in CCGT power plant cycles

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This Project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement N. 764706

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Agenda

Executive Summary

- PUMP HEAT main challenge
- Power Oriented (PO)
- Combined Heat and Power (CHP)

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PUMP HEAT Main Challenge

Combined Cycle Gas Turbine (CCGT) are facing **highly demanding efficiency and flexibility requirements** and often they are not profitable enough to avoid mothballing or closure

Heat pump integration in CCGT is as an opportunity to make CCGT the **bridging technology to a decarbonized economy** but it must win the following main challenges:

- Enhance the **plant flexibility** and **overall efficiency**
- Be **techno-thermo-economically viable** compared to already known solutions

1. Power only CCGT

2. Combined heat and power CHP

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Power Oriented CCGT

Be technically feasible:

1. **Heat Pump with R600 (Butane) as a working media**: advanced technology HP can lead to high COPs thus better impact on all thermo-economic indexes.
2. **TES size/technology and costs**: recent studies demonstrate how TES is a key enabler for HP successful integration into PO CCGTs
3. **Plant operation scheduler optimizer** is a must to properly manage the operation modes (TES charging/discharging, continuous cooling/heating) in todays and future complex market scenarios

Be thermo-economically viable:

4. The thermo-economic analysis is a challenging task due to the **unpredictability of the Ancillary Service Market** (ASM). To increase profitability from ASM:
   - **Reduce Minimum Environmental Load** (MEL) to avoid shut down and increase and availability for ASM
5. Reduce emissions and O&M costs:
   - **Reduction of intraday shutdown/startup**: a hot pressurized start-up has a costs of ca 24 keur and > 100 tons of CO2 and can be economically replaced with a turn-down period
   - **Reduce components life consumption** due to shutdown/startup

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Power Oriented CCGT

Minimum Environmental Load (MEL) reduction enhances the profitability:

1. Remain available for Ancillary Service Markey (ASM) thanks to increased turn down period

Calculated for a 400MW size CCPP

Performance variation for an increase of 30°C (from 15°C to 45°C) of GT inlet temperature.

Parameter	Net Power		Net Efficiency	
Unit	[MW]	[%]	[pt%]	[%]
CC (Heat for Free)	-30.1	-16.0	-0.8	-1.5
CC CHP (Heat from WSC)	-32.0	-17.0	-1.3	-2.7
PHCC (Heat from HP, no TES)	-32.7	-17.3	-1.6	-3.1
PHCC TES (Heat from HP, TES charging)	-35.0	-18.6	-2.3	-4.6

2. Avoid the emission related to start up procedure and the start-up impact over component aging

pollutant	u.m.	Hot P SU	Hot SU	Warm SU	Cold SU	SD
CO2	ton	78,6	108,0	127,7	196,4	19,5
NOx	kg	49	68	127	254	18
CO	kg	528	726	794	998	68

For each avoided SU/SD procedure is possible to avoid ca 98 tons of CO2, ca 67 kg of NOx and ca 596 kg Carbon Monoxide

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Combined Heat and Power (CHP)

Be technically feasible:

- **Retrofit** applications constraints **limit the performance** enhancement of the HP concept
  - Minimum steam flow rate for the LPT (to ensure a proper throughflow).
  - Minimum exhaust temperature at stack to keep sufficient buoyancy effect to increase pollutant dispersion
  - Avoid exhaust gas condensation (acid condensate)
- **New unit**: best performance enhancement with **flue gas condensation**
  - Imposes a particular layout configuration: flue gas condensing system is a technical challenge itself
  - The flue gas condenser heat exchanger has to be built with corrosion-resistant materials
  - Reheating of flue gas must be considered after the latent heat exploitation to guarantee minimum stack temperature for the buoyancy effect

Be thermo-economically viable:

1. The key enabler is the capability to **uncouple GT load and thermal energy** production
2. **High capital expenditure** for large size heat pump (ca. 10 times more than Heat Only Boiler) restricts the market conditions under which the value of the investment is positive. **Strong presence of renewable generators** will bring HP integration Net Present Value much higher than today.
3. **ASM participation** is the best scenario for HP integration profitability but it is **highly unpredictable**.

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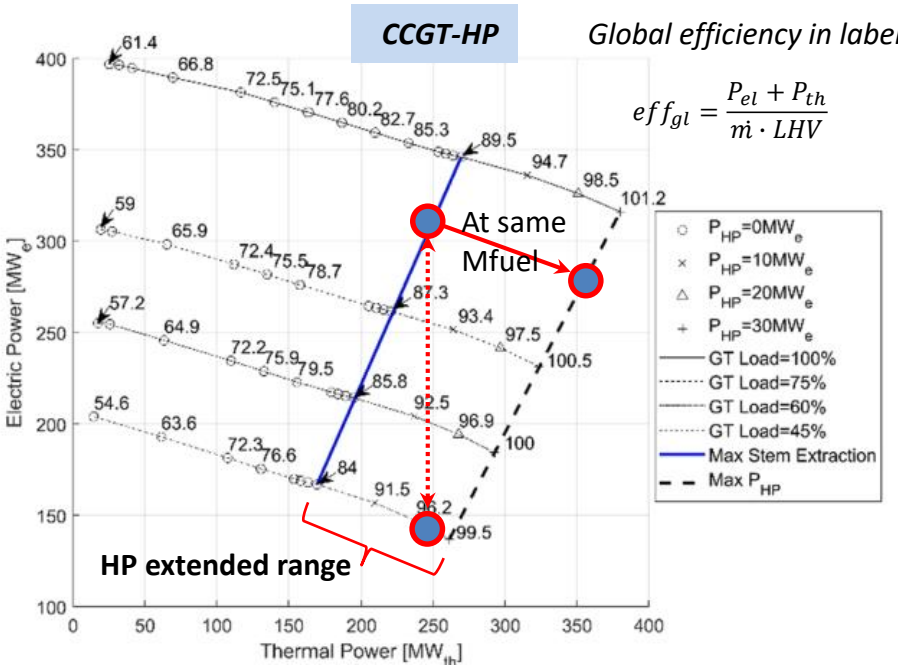
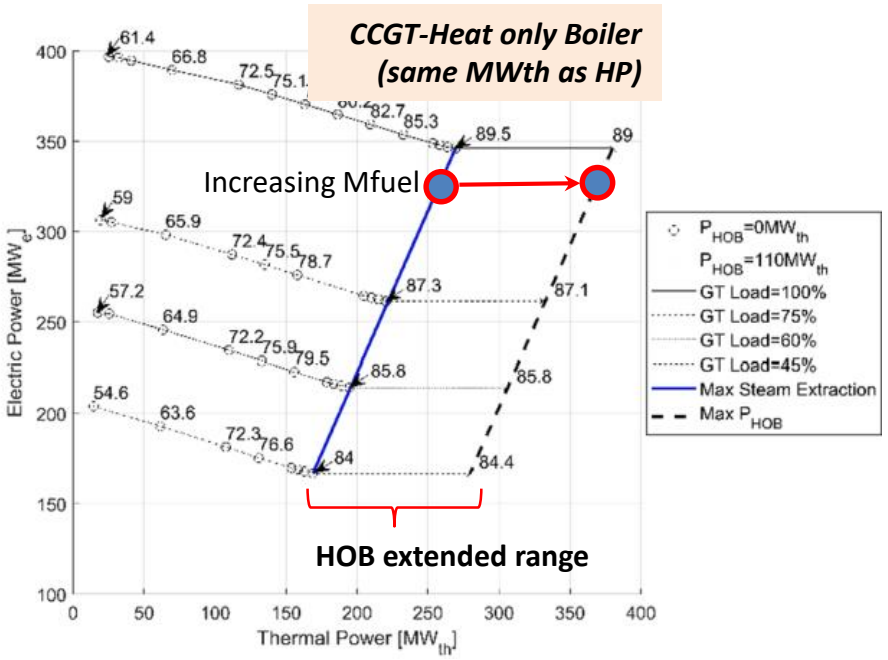
Combined Heat and Power (CHP): Uncoupling GT load and thermal energy production





The CCGT-HP allows to provide the same **additional heat as HOB without increasing the fuel consumption**

Increased global efficiency

Reduced emissions

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