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Flexibility from large-scale heat pumps

IEA HPT TCP Annex 57 Task 4

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What do we mean by flexibility?

Thermal flexibility
- Adaption of heat uptake or heat output
- Adaption of delivered temperatures

Electric flexibility
- Capability to adapt the consumed electricity at a defined node in the grid

Short-term | Mid-term | Long-term

Flexibility services to the power grid

**Implicit flexibility**
- Variable electricity price
- Variable grid tariffs

**Explicit flexibility**
- Bilateral agreements
- TSO ancillary services
- Local flexibility market
- Conditional agreements
  - Directly procured flexibility
  - Balance services, bids are activated upon calls
  - Flexibility market, bids are activated upon calls
  - Agreement with customer to adjust the power consumption when necessary
Services to the transmission system operator (TSO)

Frequency stability

Generation

Demand

Energy markets
Day-ahead market
Intra-day market
Balancing market

Ancillary services

Source: Energinet (2023). Outlook for ancillary services 2023-2040
Sector coupling using large-scale heat pumps

**Large-scale**: Here, centralized heat pumps in thermal grids

**Requirements**
- Connection to storage
- Efficient part-load operation
- Higher number of starts- and stops
- Fast reaction time (dependent on the service)
- Measurement and direct control of the power uptake
Capacity control

- Flexibility requires adaption of heat pump load
- Typically heat output is controlled directly or indirectly via the source outlet temperature
- Quick adaption of load requires optimized control of the cycle and the secondary streams to avoid sudden fluctuations that may harm the plant.

Multiple parallel compressors (On/Off, or (N-1) On/Off + 1 VSD)

Piston compressors (VSD + decoupling of cylinders)

Screw compressors (VSD + Slide valve)

Turbo compressors (adaptation of speed and guide vanes)
Factors limiting ramp-up times
Other aspects related to flexible operation

Required stand-still times

• allow for the refrigerant to settle in the foreseen receivers/vessels in the system and to stabilize the conditions within the cycle. This ensures that no liquid is compressed in the compressor and that the valve is fed with liquid to ensure a safe and stable start-up.

• prevent overheating and/or increased wear on the electric motor of the compressor. Typically, large scale motors have a limited amount of consecutive starts as well as maximum starts per year.

Temperature flexibility is given by

• Compressor envelop
• Material restrictions
• Max. and min. oil temperature
• Thermophysical properties of refrigerant and secondary medium
Example 1: FlexHeat, Copenhagen, DK

- 2-stage ammonia heat pump
- 800 kW thermal
- DH supply: 60-84°C
- Part-load: 20-100%
Example 2: CO2 heat pump in Søndre Felding, DK

- CO₂ Heat pump
- Multiple parallel compressors
- 3.3 MW thermal
- Source: Ambient air
Example 3: CO2 Heat pump, Esbjerg, DK

Max achieved process parameter (FAT Test, MAN)

- CO2 pressure: < 160 bar
- Hot supply: 60°C to 109°C
- Heat supply: 18 - 38 MWth
- Fast load change: 2 - 9 MW/30 sec
- Min evap. Temperature: -5°C
- Max evap. Temperature: 25°C
- CO2 mass measurement
- QT diagram of DH HEX (approach of approx. 1K)
- Noise emissions < 96 dB
- Wet gas Compression inlet: robust operation of Compressor
- 2-phase Expansion stage outlet: robust operation
THANK YOU FOR YOUR ATTENTION!

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