Case Studies

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ANNEX 57

Flexibility by implementation of heat pumps in multi-vector energy systems and thermal networks

Seawater HeatPump, Esbjerg, Denmark

The world's largest CO_2 seawater heat pump

The large-scale heat pumps can provide ca. 70 MW heat, while being able to react fast enough to provide primary

KEY FACTS

RD&D Status:
Commercial project

Type of heat pump:
Centralized heat pump (HP)

Building description:
Existing buildings

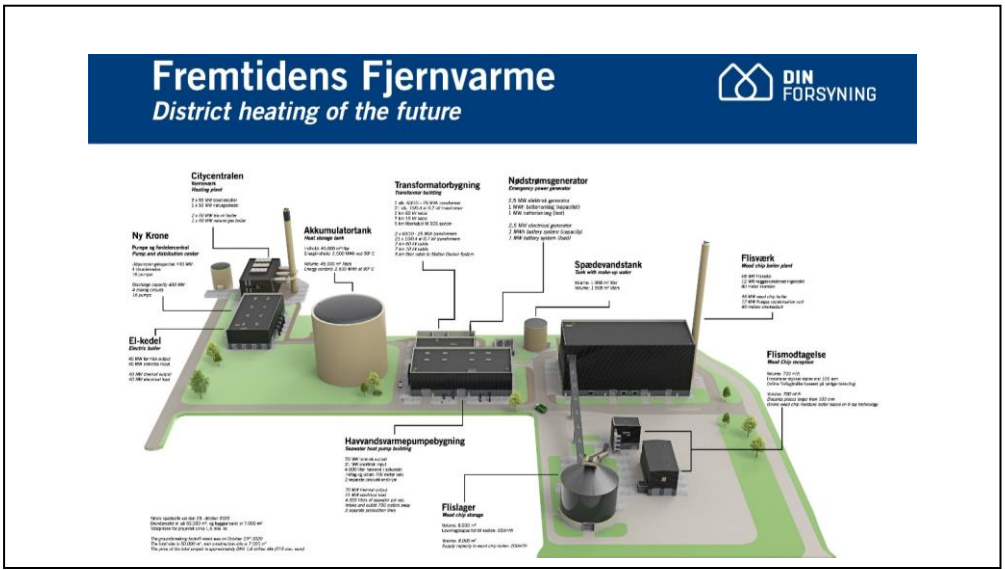
System:
District heating system providing heat to Esbjerg, Varde and Nordby.

Energy Storage:
45.000 m^3 (corresponding to 2500 MWh at 90 °C)

Control for the flexible heat pump operation:
Flexible speed drive

General description:
Two one-stage CO_2 heat pumps with compressor-expander unit with ca. 35 MW_{th}, each.

Source:
Seawater



Summary of the project:

The utility company DinForsyning in Esbjerg, Denmark is currently building the largest seawater heat pump in Denmark and the largest CO2 heat pump worldwide (status February 2023), deliver by MAN Energy Solutions. It has a nominal capacity of 70 MW heat and can deliver district heating at forward temperatures of 60 °C to 90 °C at return temperatures of around 35 °C. The plant consists of two identical CO2 heat pumps in parallel. The heat pumps use a single-stage, transcritical cycle. The compressor is a turbo compressor including an expansion unit and is equipped with a variable speed drive. The evaporator is a shell-and-plate heat exchanger. The heat pump further includes a low-pressure receiver. The heat source is seawater from the North Sea that is taken in from 600 m off the coast and reinjected at 1.5 km off the coast. The nominal seawater intake is 14000 m3/h.
The heat pump is designed to operate flexibly, i.e. it is expected to be able to ramp from minimum load to maximum load and from (hot) stand-by to full load in less than 30 seconds. The heat pump is part of the project "Fremtidens fjernvarme" (District heating of the future) of DinForsyning that further includes biomass-fired boilers, electric boilers, a large-scale storage and natural gas boilers. It will be possible to deliver frequency regulation (including primary reserve) from the heat pump alone or in combination with the other assets in the system.

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Flexible operation

The ability to ramp from 100 % load to 25 % load in less than 30 seconds and back has been demonstrated in full-scale laboratory tests at the manufacturers side. The low reaction times can be realized thanks to the one-stage heat pump cycle (low complexity of the cycle design) and the ability of the turbo compressor to adapt its load quickly. The fast load adaption at the site in Esbjerg is still to be demonstrated.

Results:

- The project demonstrates that large-scale seawater heat pumps utilizing the non-toxic natural refrigerant CO_2 are technically available and economically feasible
- The choice of heat pumps results in several benefits with regard to the ability of flexible load adaption: Compact units thanks to high volumetric heating capacity, oil-free turbo compressor-expander that can adapt the load quickly and uncomplex cycle design resulting in good controllability of the thermodynamic cycle.
- It is possible to adapt the heat pump load quick enough to deliver primary frequency regulation (reaction time less than 30 seconds). Possibly in connection with electric boilers in the system, to provide both down and up regulation.

FACTS ABOUT THE PROJECT

Place:
Esbjerg, Denmark

Time Frame:
2017-2023

Project owner/leader:
DinForsyning

Manufacturer:
MAN Energy Solutions

Consultants:
Added values

Contact Information/Links

DinForsyning
https://dinforsyning.dk/
https://fremtidensfjernvarme.dk/

AddedValues
https://addedvalues.eu

Published articles:

AddedValues. (n.d.). *Derfor er havvandsvarmepumperne så fascinerende*. Retrieved September 22, 2023, from https://addedvalues.eu/c/nyheder/derfor-er-havvandsvarmepumperne-saa-fascinerende

Jørgensen, K., Nielsen, C. A., & Mølbak, T. (n.d.). *Havvandsbaseret varmepumpe bliver hjertet i fremtidens fjernvarmeforsyning i Esbjerg*. Retrieved September 22, 2023, from https://addedvalues.eu/c/nyheder/havvandsbaseret-varmepumpe-bliver-hjertet-i-fremtidens-fjernvarmeforsyning-i-esbjerg

Wolscht, L. ; Knobloch, K. ; Jacquemoud, E. ; & Jenny, P. (2023). Dynamic Simulation and Experimental Validation of a 35 MW Heat Pump Based on a Transcritical CO 2 Cycle. *Citation*, 93–105. https://doi.org/10.17185/duepublico/77273

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