Using heat pump to recover waste heat from thermal power plants for district heating

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Current situation of district heating (DH) in China

- DH demand in north China accounts for about 40% of the total building energy consumption.
- The DH demand in China is growing rapidly. At the end of year 2012, the total DH production of China was over $2 \times 10^7$ TJ, and the production increment per year is about $2 \times 10^6$ TJ.
- DH production share:

  ![DH production technologies in China](image)

Fig. 1. DH production technologies in China.
Building climate zones in China

1 – extremely cold area; 2 – cold area; 3 – hot summer and cold winter area; 4 – mild area; 5 – hot summer and warm winter area.

Fig. 2. Building climate zones in China.
Fig. 3. Power plant technologies in China, a) Capacity equipped and b) power production, in 2012.

- Thermal power plant efficiency, typically around 40%.
- Main reason: Condensing loss! + Flue gas
- In 2005, about $3.4 \times 10^8$ t standard coal (equivalent) was completely wasted as condensing loss. This amount of coal can account for 15% of total energy consumption or 36% of the building energy consumption in China in 2005!
How to increase power plant efficiency when connecting to DH

1. **Change the operation conditions of steam turbines in power plants**
   - Reduce the vacuum extent (increase the absolute pressure) in exhaust hood of a turbine and thus increase the temperature of exhausted steam for heating; this is called *low vacuum operation of steam turbine*.

2. **Use the heat pump to absorb the waste heat in cooling water (cooling water as the low grade heat source).**
   - Absorption heat pump
   - Electrical heat pump
   - Steam driven compressor heat pump
   - Mechanical heat pump
Using absorption heat pump to recover waste heat in cooling water

Fig. 4 Schematic flow chat of DH system based on distributed absorption HP.

1 – Steam turbine
2 – Condenser
3 – Cooling tower
4 – Absorption heat pump
5 – Absorption heat exchanger
Using absorption heat pump to recover waste heat in cooling water - 2

Thermal power plant

Fig. 5 DH system based on centralized absorption HP.

1 – Steam turbine
2 – Condenser
3 – Cooling tower
4 – Absorption heat pump
5 – Steam-water heat exchanger

Primary network
Using absorption heat pump to recover waste heat in cooling water - 3

- **Distributed absorption heat pump system**
  - Reduce the DH return water temperature, and thus increase the useful temperature drop in the DH network;
  - Increase the heat delivery capacity of the DH network;
  - Increase the COP of the absorption heat pump in the power plant, because of the lower return DH water temperature.
  - More pipeline construction is required.

- **Centralized**
  - Cascade energy utilization;
  - COP is not high because of the high DH return water temperature;
Using electrical heat pump to recover waste heat in cooling water

Fig. 6 The schematic flow chart of DH system based on decentralized electrical HP.

1 – Steam turbine
2 – Condenser
3 – Cooling tower
4 – Electrical heat pump
Using electrical heat pump to recover waste heat in cooling water-2

Fig. 7 The schematic flow chart of DH system based on centralized electrical HP.

1 – Steam turbine
2 – Condenser
3 – Cooling tower
4 – Electrical heat pump
5 – Steam-water heat exchanger
Using electrical heat pump to recover waste heat in cooling water-3

- Distributed electrical heat pump system
  - Cooling water flow to the substation directly, and it is cooled down in the electrical heat pump;
  - More construction of the pipeline network;
  - Due to the small available temperature drop, pump cost is high and heating radius is small;

- Centralized
  - Cascade energy utilization;
  - Less construction of pipeline network.
Discussion

- Distributed v.s. centralized?
- Possible Combination?
- Promising Combination
  - Electrical HP in CHP + Distributed absorption heat exchanger in secondary network
  - Why? Heat and power demands + heat production from the cooling water is affected by the power production (coupled though not CHP) + the use of heat storage in the power plants + peak shaving requirement (heat and power) + optimal operation of the plants…
- Detailed techno-economic analysis is needed.
Thank you for your attention!