Smart integration of power to heat technology in thermal networks

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NEXT GENERATION ENERGY SYSTEM WILL BE BUILT:

FED BY RENEWABLE SOURCES AND WASTE HEAT

CONTROLLED WITH INTELLIGENCE

LOW TEMPERATURE

130°C
100°C
80°C
60°C
40°C
INTERMITTENT SOURCES OF ELECTRICITY

FED BY RENEWABLE SOURCES AND WASTE HEAT

CONTROLLED WITH INTELLIGENCE

HEAT PUMPS INTEGRATED WITH DISTRICT HEATING

LOW TEMPERATURE

THERMAL NETWORK AT LOWER TEMPERATURE

CONVENIENCE OF USING HEAT PUMPS INTEGRATED WITH DISTRICT HEATING
SEVERAL WAYS TO INTEGRATE HEAT PUMPS INTO DISTRICT HEATING (SUPPLY, RETURN, DIFFERENT LOCATIONS)

WHERE TO LOCATE THE HEAT PUMP IN A DISTRICT HEATING SYSTEM (IN THE MOST FAVOURABLE WAY)?
BEST LOCATION DEPENDS ON:

1. THE THERMAL LOSSES ALONG THE NETWORK
2. THE PROCESSED MASS FLOW RATE
3. THE TYPE OF THERMAL PLANT THE RETURN MASS FLOW IS PROCESSED TO

DEPENDS ON THE THERMAL DYNAMIC OF THE NETWORK
DEMAND OF BUILDINGS

NETWORK

THERMAL LOAD AT THE PLANTS

NETWORK PHYSICAL MODEL
MASS CONSERVATION EQUATION
N nodes of the network

\[ A \cdot G + G_{\text{ext}} = 0 \]

MOMENTUM EQUATION
M branches of the network

\[ G = Y \cdot A^T \cdot P + Y \cdot \Delta p_{\text{pumps}} \]

ENERGY EQUATION
N nodes of the network

\[ M \cdot \dot{T} + K \cdot T = g \]
NETWORK TOPOLOGY

HEATING REQUEST PROFILES

SIMULATOR
NETWORK DYNAMICS

TEMPERATURE AND MASS FLOW RATES IN THE ENTIRE NETWORK

EXAMPLE OF A DISTRIBUTION NETWORK SIMULATION
BEST LOCATION FOR THE HEAT PUMP

COEFFICIENT TO BE MAXIMIZED

$$\phi = \frac{E_{fuel, without \ HP} - E_{fuel, with \ HP}}{W_{el, HP}}$$

FUEL SAVED (EXERGY ASSOCIATED)

ELECTRICITY ABSORBED BY THE HEAT PUMP

The **largest** district heating network in Italy:

- 55% of the buildings are connected (**700,000 inhabitants**)
- **800 km** of double pipes
- **182 distribution networks**
RESULTS

- ONLY CHP
- CHP AND BOILERS
- ANNUAL RESULT
CASE 1
ONLY CHP

LOCATION NEAR THE THERMAL PLANTS BECAUSE OF:
• LOWER THERMAL LOSSES
• HIGHEST MASS FLOW RATES

CONVENIENT FOR INSTALLATION CLOSED TO THE PLANT WITH LARGER OPERATING HOURS
CASE 2a
CHP AND HEAT ONLY BOILER

LOCATION NEAR THE HEAT ONLY BOILER BECAUSE OF:

• LOWER THERMAL LOSSES
• NO PERFORMANCES DECREASE OF CHP PLANTS
CASE 2b
CHP AND HEAT ONLY BOILER

LOCATION NEAR THE HEAT ONLY BOILER
CASE 3
CHP AND HEAT ONLY BOILER

\( \bar{\varphi} \), is defined taking into account the time each scenario occurs:

\[
\bar{\varphi} = \sum_{i=1}^{NS} p_i \varphi_i
\]

where \( NS \) is the total number of scenarios while \( p_i \) is the time percentage the scenario \( i \) occurs.

Optimal position for the system considered will be the one with maximum \( \bar{\varphi} \).
CASE 3  

CHP AND HEAT ONLY BOILER

NEAR THE BOILER2  
(NO DECREASE IN CHP PERFORMANCES AND LOWER THERMAL LOSSES)

NEAR BOILER1 AND CHP1  
(VERY HIGH MASS FLOW RATES AND LOWER THERMAL LOSSES)

• $\bar{\varphi}$ maximum occurs in an intermediate point
CONCLUSIONS

SMART INTEGRATION OF HEAT PUMPS IN DISTRICT HEATING SYSTEMS

THE POSITION OF INSTALLATION SHOULD BE DONE CONSIDERING ALL THE ANNUAL OPERATING CONDITIONS

INSTALLATION POSITION AFFECTS THE OVERALL PERFORMANCES

SMART INTEGRATION OF HEAT PUMPS IN DISTRICT HEATING SYSTEMS

A THERMO-FLUID DYNAMIC MODEL OF THE NETWORK SHOULD BE USED TO EVALUATE MASS FLOW RATE, TEMPERATURE AND LOSSES

WHERE MASS FLOWS ARE HIGHER PERFORMANCES ARE HIGHER, BUT THIS IS NOT THE ONLY POINT

INFLUENCE OF THERMAL LOSSES AND TYPE OF THERMAL PLANT ARE NOT NEGLIGIBLE
THANK YOU
FOR THE ATTENTION

This work has been conducted within the European Project H2020-LCE-2016-2017 PLANET (Planning and operational tools for optimizing energy flows and synergies between energy networks)

https://www.h2020-planet.eu/
Analisi dell’installazione di una pompa di calore in una rete di teleriscaldamento

1. Con un modello termo-fluidodinamico della rete si valuta la temperatura dell’acqua che rientra in centrale

\[ T_{r,\text{centr}} \ [^\circ C] \]

2. Si calcola la potenza termica richiesta dalla centrale

\[ \Phi_{\text{centr}} = G_{\text{centr}} c_p (120^\circ C - T_{r,\text{centr}}) \ [W] \]

3. Si stima l’exergia associata a tale flusso termico

\[ E = \Phi_{\text{centr}} \left( 1 - \frac{T_0}{120^\circ C + T_{r,\text{centr}}} \right) \ [W] \]

4. Infine, attraverso il rendimento di secondo principio, si calcola l’exergia associata al combustibile utilizzato

\[ E_{\text{fuel}} = \frac{E}{\eta_{\text{II}}} \ [W] \]
CONCLUSIONS

1. **Installation Position Affect the Overall Performances**
   - Installation position should be done considering all the annual operating conditions.

2. **Smart Integration of Heat Pumps in District Heating Systems**
   - Smart integration of heat pumps in district heating systems affect the overall performances.

3. **A Thermo-Fluid Dynamic Model of the Network**
   - A thermo-fluid dynamic model of the network should be used to evaluate mass flow rate, temperature, and losses.

4. **Where Mass Flow Are Higher Performances Are Higher**
   - Where mass flow are higher, performances are higher.

5. **Influence of Temperature of Water Affect a Lot the Position of the HP (Because of the Different COP)**
   - Influence of temperature of water affects a lot the position of the HP (because of the different COP).
Analisi dell’installazione di una pompa di calore in una rete di teleriscaldamento

- Il rendimento di secondo principio viene assunto costante.
- Per le centrali cogenerative di Moncalieri e Torino Nord:

\[ \eta_{II, CHP} = \frac{W_{el} + \Phi \left(1 - \frac{T_0}{T}\right)}{E_{fuel}} = 56,3\% \]

- Per l’impianto di integrazione del Politecnico:

\[ \eta_{II, Boiler} = \frac{\Phi \left(1 - \frac{T_0}{T}\right)}{E_{fuel}} = 19,6\% \]
OPTIMIZATION APPROACH TO FIND THE BEST LOCATION FOR THE HEAT PUMP STORAGE