Improved methodology for testing the part load performance of water-to-water heat pumps

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Work description

Rationale:

• Continued expansion in the implementation of heat pumps in buildings leads to a strong need to characterise the energy performance of these systems
• Variable speed heat pumps increasingly applied in the residential sector, however, fixed capacity heat pumps are still widely used and implemented in larger buildings

Work objective:

• No existing rating methods have been validated for fixed capacity heat pumps at partial load
• An improved experimental methodology is developed for characterising the performance of fixed-capacity heat pumps at partial load
Experimental set up: semi-virtual testing
Combination of experimental facility with simulation model

Real heat pump: Dynaciat, water to water heat pump of 40.3 kW heating capacity

Virtual load and distribution system

Load

Heat Storage

Set deltaT temperature

Energy rates

Type65d

Type25c
Influence of inertia on heat pump performance

- Loss of efficiency with lower inertial volume
- $\text{PLR} = \frac{\text{Load}}{\text{Capacity}_{\text{steady state}}}$
- $\text{PLF} = \frac{\text{COP}_{\text{steady state}}}{\text{COP}}$
Start-up and stand-by losses: correlations

$$PLF = 1 - C_d(1 - PLR)$$  \hspace{1cm} \text{ARI 210/240}

$$PLF = \frac{PLR}{Z} = \frac{PLR}{a \cdot PLR + b}$$  \hspace{1cm} \text{UNI 10963}

$$PLF = \frac{PLR}{C_c \cdot PLR + (1 - C_c)}$$  \hspace{1cm} \text{EN14825}

New correlation

$$PLF = \frac{1}{1 + C_d(1 - PLR) + (1 - C_c) \frac{1 - PLR}{PLR}}$$
New Methodology

- 1 experiment at stand-by conditions to determine Cc (stand-by coefficient)
- 1 experiment at partial load
- Use new equation to find Cd (start-up loss coefficient) by matching the correlation output to the experimental data at part load.

\[ PLF = \frac{1}{1 + \frac{C_d(1 - PLR)}{1 - C_d(1 - PLR)} + (1 - C_c) \frac{1 - PLR}{PLR}} \]

![Graphs A, B, and C showing comparison between experimental data, UNI method, and new reduced method.](image-url)
Estimations of annual COP (EN14825)

More accurate estimation of performance that existing methods in standards
Heat pump fixed-capacity transient model

Distribution system not considered  Distribution system considered

Steady-state behaviour

\[
\dot{Q}_{\text{cond}} = c + d \ T_{\text{evap.in}} + e \ T_{\text{cond.in}} \\
\dot{Q}_{\text{evap}} = f + g \ T_{\text{evap.in}} + i \ T_{\text{cond.in}} \\
\dot{P}_{\text{elec}} = j + k \ T_{\text{cond.in}} + l \ T_{\text{cond.in}}^2
\]

Start-up

\[
\dot{Q}_{\text{cond, start-up}} = \dot{Q}_{\text{cond}}(b_1 t + b_2 t^2 + b_3 t^3 + b_4 t^4 + b_5 t^5 + b_6 t^6)
\]
Summary and conclusions

• Semi-virtual experiments are conducted to characterise the behaviour of a fixed-capacity heat pump
• Heat pump performance is found to be highly influenced by inertia conditions and their effect on stand-by and start-up losses
• An improved reduced experimentation method is proposed to characterise the performance of a heat pump under partial load conditions
• Better estimations at lowest experimentation cost is achieved with the novel method
• Black box modelling of fixed capacity heat pumps: able to model transient behaviour, which is highly influenced by inertia in the installation