Romanian Journal of Civil Engineering, Volume 16 (2025), No. 1

Heating systems using heat pump thermal adjustment

Sisteme de încălzire care utilizează reglajul termic al pompei de căldură

Florin IORDACHE[1], Mugurel TALPIGA[1]

[1] Technical University of Cvil Engineering Bucharest
Bd. Lacul Tei nr. 122 - 124, cod 020396, Sector 2, Bucharest, Romania

E-mail: fliord@yahoo.com, talpiga.mugurel@gmail.com

DOI: 10.37789/rjce.2025.16.1.10

Abstract: The objective of the work is an analysis of the adjustment performed on the electric power absorbed by the heat pump to ensure the thermal regulation of the central heating installation. The situation in which the heat pump is the only source that supplies the heating system was considered. The heat pump must therefore be sized to have the capacity to cover the consumer's calculated heating needs. It is presented in the work the importance of the dimensioning principle of the heating system: high temperature, medium temperature, and low temperature heating systems. The importance of the climatic zone on the capacity of the heat pump is also required.

Cuvinte cheie: pompă de căldură, reglaj termic

Rezumat: Lucrarea are ca obiectiv o analiza asupra reglajului efectuat asupra puterii electrice absorbite de pompa de caldura pentru asigurarea reglajului termic al instalatiei de incalzire centrala. S-a considerat situatia in care pompa de caldura este singura sursa care alimenteaza instalatia de incalzire. Pompa de caldura, se impune in consecinta sa fie dimensionata a avea capacitatea de a acoperii necesarul de incalzire de calcul al consumatorului. Se prezinta in cadrul lucrarii Importanta pincipiului de dimensionare al instalatiei de incalzire : instalatie de temperatura ridicata, temperatura medie si temperatura joasa. Se remerca si importanta zonei climatice asupra capacitatii pompei de caldura.

Key-words: heat pump, thermal adjustment

Introduction

The heat pump can be a source of thermal energy for a central heating system or/and for a domestic hot water preparation system. If it is the only source of energy for the building's central heating system, then its dimensioning must be done accordingly. An important problem, however, is the provision of thermal power regulation of the

The article was received on 03.03.2024, accepted on 24.02.2025 and published on 14.03.2025

system, regulation that must be ensured by the heat pump through the regulation of electric power absorbed from the national system. Both the capacity of the heat pump and its power regulation are dependent on a series of parameters that intervene both in the definition of the heat pump but equally in the definition of the central heating system.

Methodology

The paper will insist on the importance of the parameters related to the building and the central heating system in determining the dimensioning and regulation of the heat pump. We refer to the thermal transfer capacity of the building envelope, Hinc (W/K), the climatic zone in which the building is located by the calculated external temperature, te0 (oC), and the dimensioning hypothesis of the central heating system: high temperature system (tT0/tR0 = 90/70 oC), medium temperature system (tT0/tR0 = 70/50 oC), and low temperature system (tT0/tR0 = 50/30 oC). It is known that between the 3 types of systems mentioned, an important difference is the size of the heating surface, which is large in the case of the low temperature system, medium in the case of the medium temperature system and small in the case of the high temperature system. We do not propose however, within this work, let's also analyze the correlation between the heating system sizing principle and the size of the heating surface.

Regarding the heat pump, the considered parameters are the isentropic efficiency of the compressor η_{iz} and the efficiency of the electric motor, η_{el}. The nominal electric power is the one that is determined based on the calculated heat requirement of the building as will be presented below. The relationships used were also presented in previous works [1], [2] and [3]. Thus, considering the expression of the temperature of the thermal agent according to compliance with the qualitative thermal regulation, it results:

$$\Delta\theta = \theta_{CD} - \theta_{VP} = t_T - t_e = \left(1 + \frac{t_{T0} - t_{i0}}{t_{i0} - t_{e0}} \cdot \frac{1 - E_0}{1 - E}\right) \cdot \left(t_{i0} - t_e\right)$$

$$\textit{with simplified form } \left(E = E_0\right): \tag{1}$$

$$\Delta\theta = \theta_{CD} - \theta_{VP} = t_T - t_e = \left(1 + \frac{t_{T0} - t_{i0}}{t_{i0} - t_{e0}}\right) \cdot \left(t_{i0} - t_e\right)$$

The simplified form refers to the consideration of a constant value of the global thermal transfer coefficient, k, of the heating surface. Regarding the expressions of the energy efficiency of the machine as a heat pump and as a refrigeration machine, these are respectively:

$$COP = \eta_{EL} \cdot \left(1 + \eta_{iz} \cdot \left(M \cdot 86.864 \cdot \Delta\theta^{-0.759} - N\right)\right)$$
$$EER = \eta_{EL} \cdot \eta_{iz} \cdot \left(M \cdot 86.864 \cdot \Delta\theta^{-0.759} - N\right) \quad ; \quad (2)$$

Thermal and electrical powers can be written as bellow:

$$\begin{aligned} P_{CD} &= COP \cdot P_{EL} \\ P_{VP} &= EER \cdot P_{EL} \\ P_{CD} &= P_{VP} + \eta_{EL} \cdot P_{EL} \\ P_{INC} &= H_{INC} \cdot (t_{i0} - t_e) \end{aligned} \quad (3)$$

Referring to the simplified form for a more synthetic exposition, when sizing (choosing) the heat pump, the maximum power given by the condenser must be equal to the calculated heat requirement:

$$\begin{aligned} P_{CD0} &= P_{INC0} \\ COP_0 \cdot P_{EL0} &= H_{INC} \cdot (t_{i0} - t_{e0}) \end{aligned} \quad (4)$$

Where:

$$COP_0 = \eta_{EL} \cdot \left(1 + \eta_{iz} \cdot \left(M \cdot 86.864 \cdot \Delta\theta_0^{-0.759} - N\right)\right)$$
$$with:$$
$$\Delta\theta_0 = \theta_{CD} - \theta_{VP} = t_{T0} - t_{e0} = \left(1 + \frac{t_{T0} - t_{i0}}{t_{i0} - t_{e0}}\right) \cdot (t_{i0} - t_{e0}) \quad (5)$$

Then:

$$P_{EL0} = \frac{H_{INC} \cdot (t_{i0} - t_{e0})}{COP_0} \quad (6)$$

Next, the current thermal power in operation is determined based on the required thermal power of the consumer and the COP associated with the current operating situation according to relation (2). In the current operating situation, the power absorbed by the vaporizer and supplied to the condenser results quite easily according to the relations presented. In current operation, the temperature of the thermal agent at the entrance to the heating installation is given by the well-known qualitative thermal regulation relationship and consequently we have the relationships (1).

For thermal and electrical powers we obtain:

$$P_{EL} = \frac{H_{INC} \cdot (t_{i0} - t_e)}{COP}; \quad \frac{P_{EL}}{P_{INC}} = \frac{1}{COP}$$
$$P_{VP} = EER \cdot P_{EL}; \quad \frac{P_{VP}}{P_{INC}} = \frac{EER}{COP} \tag{7}$$
$$P_{CD} = COP \cdot P_{EL};$$

Simulation

The set of temperatures of the thermal agent (t_{T0}/t_{R0}) chosen for the sizing of the central heating system, was identified as an important parameter on the energy results. The following figures show these results regarding the energy efficiencies, the thermal and electrical powers involved and the ratios between them.

In fig. 1 the energy efficiency of the heat pump increases as the outside temperature is higher. The considered heat pump is of the air-water type and the result obtained is natural. It can also be seen from fig.1 that the adoption of a lower temperature level of the thermal agent in the heating system leads to an increase in the energy performance of the heat pump.

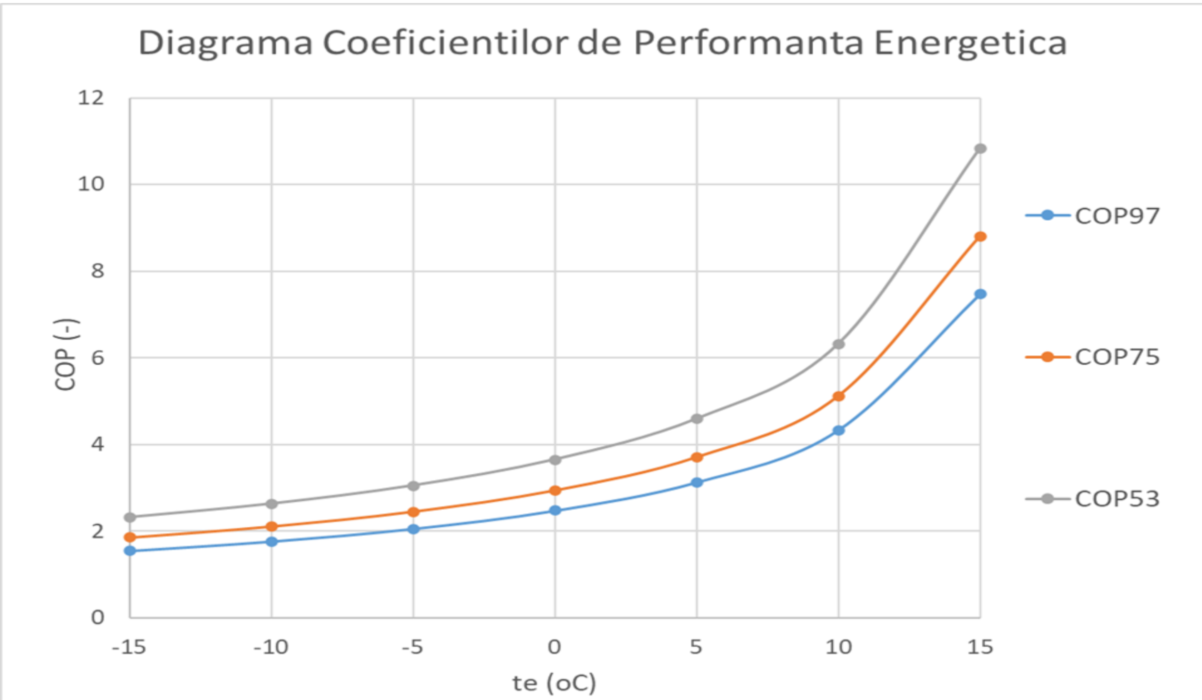

Fig. 1

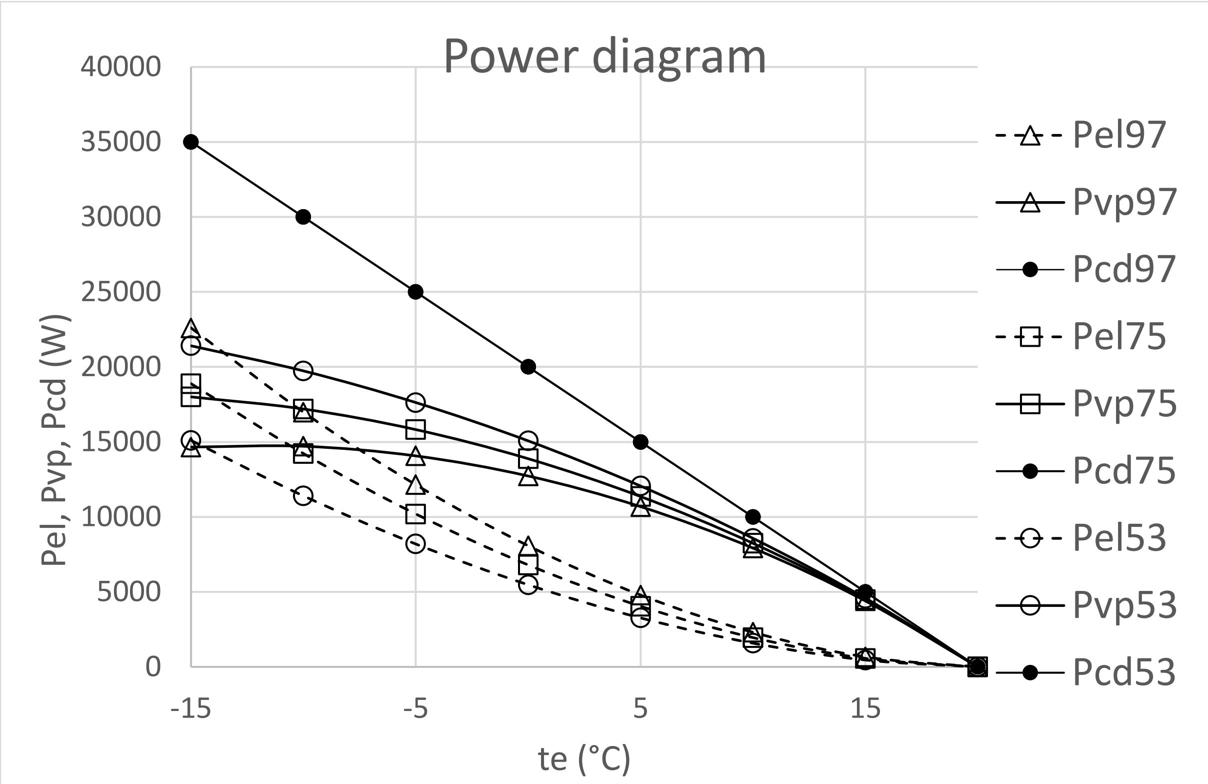

Fig. 2

Fig. 2 shows a diagram of the actual values of the thermal powers obtained in the case of a consumer characterized by a heat transfer capacity of the building in the amount of Hinc = 1000 W/K. It is observed that if the dimensioning of the heating system was made according to a lower level of the temperatures of the heating agent (respectively (tT0/tR0 = 50/30 oC)) the result is a lower electrical power absorbed from the national system associated with a lower thermal power higher absorbed at the level of the heat pump evaporator.

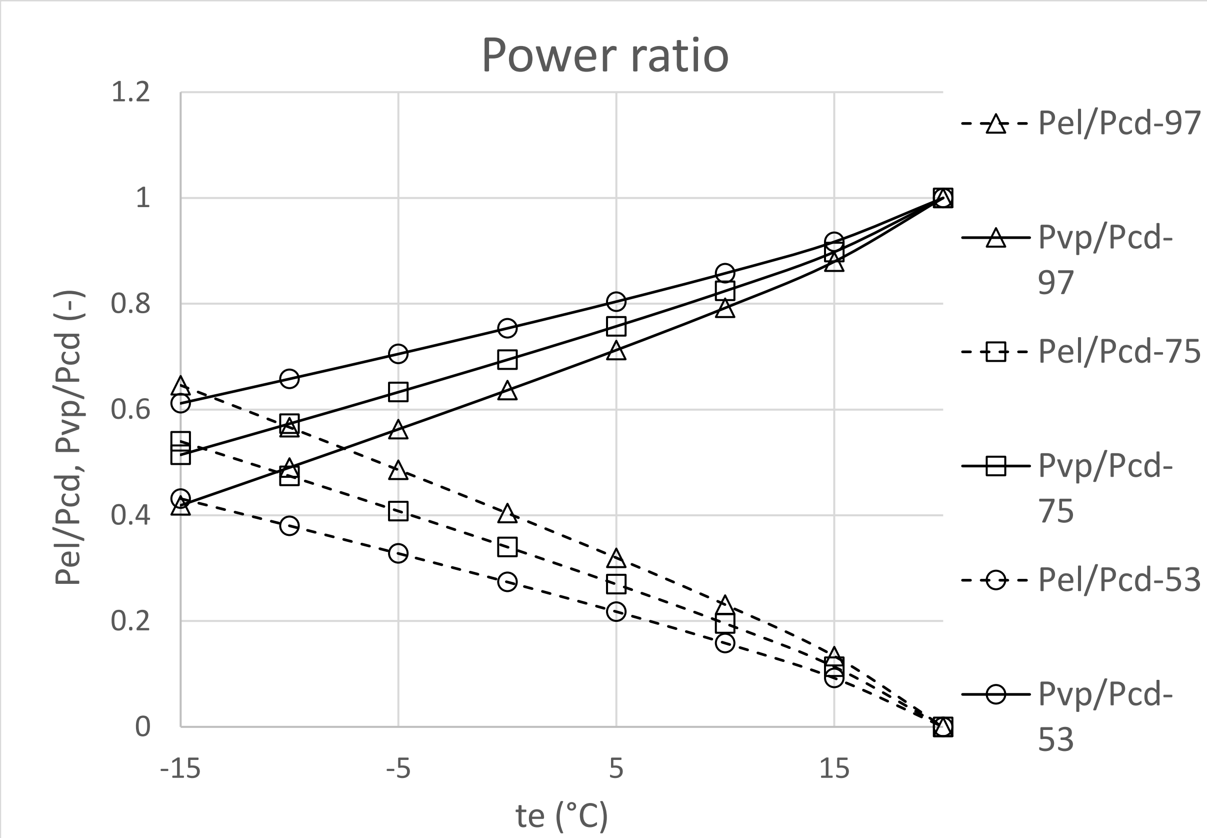

Fig.3

Fig.3 shows the ratio diagram between the absorbed electric power and the required power of the consumer and between the thermal power absorbed at the heat pump evaporator and the required power of the consumer. And these reports presented in fig. 3 express the same conclusion from the previous figures, that the sizing of heating installations at lower temperature levels is beneficial for the adoption of the heat pump as an energy source.

Discussions

From an energetic point of view, adopting a heat pump as an energy source for a heating system is superior to using a thermal plant. Its performance is all the greater as the heating system is characterized by a larger surface resulting from the adoption of a lower temperature level of the heating agent. Based on the presented relationships, it is easy to carry out an economic analysis in which to consider the additional investments and the reductions in operating costs due to a lower level of temperatures of the thermal agent in the central heating system.

Abbreviations

t_{i0} – design internal temperature, ºC;
t_{e0} – design external temperature, ºC;

t_e – external temperature, °C;
t_{T0} – worst case scenario design heating system fluid exit temperature, °C;
t_{R0} – worst case scenario design heating system fluid input temperature, °C;
t_T – design building heating fluid input temperature, °C;
θ_{CD} – condenser temperature, °C;
θ_{VP} – evaporator temperature, °C
$\Delta\theta$ – condenser and evaporator temperature difference, °C;
H_{INC} – building heating capacity, W/K;
P_{EL} – heat pump electrical power consumption, W;
P_{EL0} – worst case scenario heat pump electrical power consumption, W;
P_{CD} – condensing thermal power, W;
P_{CD0} – worst case scenario condensing power, W;
P_{VP} – evaporator power, W;
P_{INC} – building heating demand, W;
COP_0 – worst case scenario Coeficient of Performance, -;
COP – Coefficient of Performance, -;
EER – energy efficiency ratio, -;
E – building heating facility thermal module; -
η_{EL} – electrical compressor efficiency, -;
η_{iz} – izentropic efficiency, -;
M=0.958, N=1.5321 – working parameters in the correlation between isentropic efficiency and Carnot efficiency $\varepsilon_{iz} = M \cdot \varepsilon_C - N$ and: $\varepsilon_C = 86.864 \cdot \Delta\theta^{-0.759}$ - Carnot efficiency, -;
COP97, COP75, COP53 – COP of 3 cases t_{T0}/t_{R0} = 90/70 °C, 70/50 °C, respectively 50/30 °C;
Pel97, Pvp97, Pcd97 – electrical power, evaporator respectively condenser por for the case t_{T0}/t_{R0} = 90/70 °C;
Pel75, Pvp75, Pcd75 – electrical power, evaporator respectively condenser por for the case t_{T0}/t_{R0} = 70/50 °C;
Pel53, Pvp53, Pcd53 – electrical power, evaporator respectively condenser por for the case t_{T0}/t_{R0} = 50/30 °C;

References:

[1] - Procedura de evaluare a indicatorilor de performanta pentru masini frigorifice sau pompe de caldura – Florin Iordache, Alexandru Draghici – Revista Romana de Inginerie Civila, Volumul 10 (2019) nr. 4 – Matrix Rom, Bucuresti;

[2] – Procedura simplificata de evaluare a performantei energetice a pompelor de caldura. Analiza energetica si economica – Florin Iordache, Mugurel Talpiga - Revista Romana de Inginerie Civila, Volumul 13 (2022) nr. 4 – Matrix Rom, Bucuresti;

[3] – Modelarea functionarii echipamentelor si sistemelor termice aferente cladirilor – Florin Iordache – editura Matrix Rom, 2021, Bucuresti;