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District heating and gas engine heat pump: Economic analysis based on a case study

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Abstract

"S. Nicola" HVAC plant in Vicenza features innovative and significant energy savings characteristics. It has been set up by a gas engine heat pump (coupled to two condensing boilers) whose performances are here evaluated during three years of operation. Due to a grid expansion, the University received the offer of being connected to the district heating grid. This possibility that is often considered advantageous was economically evaluated. As a result of this, a significant increasing of the building annual energy bill was demonstrated in case of acceptance.
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Keywords: Heat pump; Natural gas; Condensing boiler; Savings; District heating

1. Plant description

"S. Nicola" is the site of the Department of Industrial and Management Engineering of the University of Padova (Italy) in its Vicenza branch. The building is very old (13th Century) and it was completely renewed some years ago to host the Management Engineering degree. The HVAC plant is therefore completely new and is set up by:

(a) Heating and cooling plant (natural gas internal combustion—i.c.—engine heat pump/chiller and condensing boilers);
(b) Ventilation and air conditioning plant (21,700 m^3/h air handling unit (AHU) to control relative humidity and for the necessary air changing inside the building). The unit is set up by a mix flow heat exchanger, pre-heating, cooling and dehumidification and post-heating sections;
(c) Air extraction plant (for service rooms).

In the following analysis only the heating and cooling plant has been considered. The main component is a reversible air/water gas engine heat pump. The nominal cooling power is 275 kW (22 Nm^3/h of natural gas is the nominal fuel consumption), while in heating mode the output power is 380 kW (19 Nm^3/h fuel consumption) [1]. These performances are labelled for summer external air 35 °C and evaporator input/output 12/7 °C; winter external air 10 °C and condenser input/output 40/45 °C. Heat recovery is taken from the lubricating oil, engine cooling water and partly from the exhaust. The nominal power thus recovered is 109 kW in heating mode and 127 kW in cooling mode, to produce hot water at about 70 °C. Fig. 1 shows the i.c. engine with heat recoveries on the left and the heat pump on the right (C = condenser; E = evaporator). The energy balance of the system is reported as relative units (primary

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Nomenclature

E	annual electrical energy or annual thermal load (kWh or kJ)
P	electrical power (kW)
C	annual natural gas consumption (Standard cubic meter, Sm^3)
R	fixed cost in electrical energy bill (€/year)
S	installed power cost in electrical energy bill (€/(kW year))
T	energy cost in electrical energy bill (€/kWh)

Subscripts

el	electrical
chil	chiller
year	per year
cool	cooling
heat	heating
summ	summer
win	winter
theor	theoretical
2001	refers to 2001 quantities
inst	installed

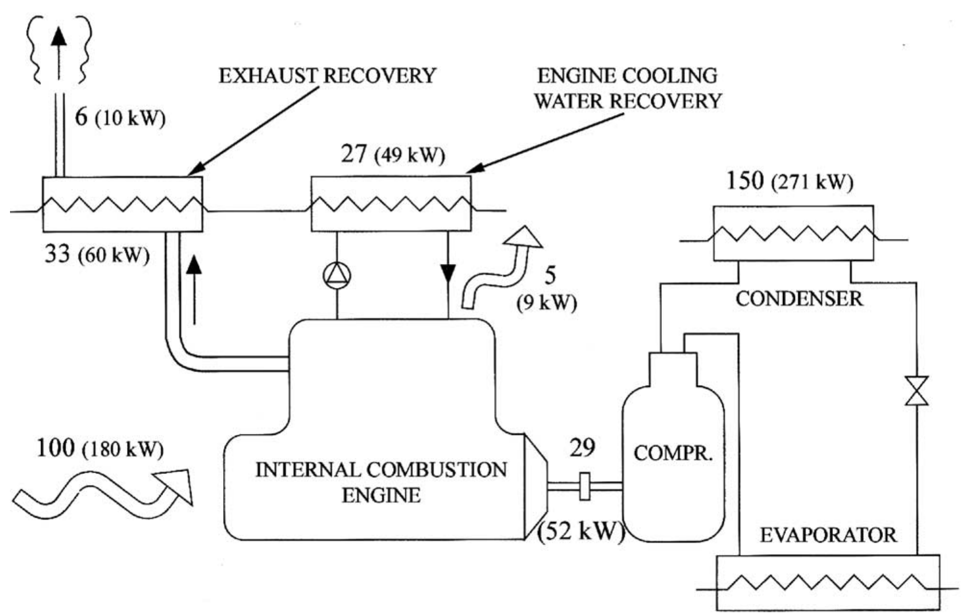

Fig. 1. Schematic figure of the gas engine heat pump installed in the "S. Nicola" HVAC plant (values reported refer to heating mode).

energy input = 100) and in absolute values (kW) for heating mode.

Two hydraulic circuits are provided. The primary one supplies chilled water in summer (7/12 °C) and warm water in winter (45/40 °C) produced by the heat pump and the secondary one hot water at 70 °C given by the heat recovery. The control system is governed by a microprocessor that commands the engine speed regulator and the compressor cylinders chocking. Two energy stores in the plant (a water tank of 3,000 l in the primary circuit and another one of 1,500 l in the secondary circuit) stabilise engine operations.

Two condensing boilers (285 kW each) provide the necessary integration. In fact the heat pump is sized to satisfy the mean winter load. The boilers operate to integrate heat both to the primary circuit or, controlled by some thermostat, separately one to the primary and the other to the secondary. In summer, supplied cooling power (287 kW)[1] is much less than the nominal load (600 kW); anyway, because of the educational destination of the building, in July and August, when outside conditions are heavier, the internal load is lowered because no lectures are provided in the lecture halls that are occasionally used just for examinations and only the offices must be served. Both the Air Handling Unit (AHU) and fan coils in the building are supplied by water as a thermal vector.

[1] Supplied cooling power is referred to summer external condition, that is 32 °C and 50% relative humidity, so it is different from nominal cooling power cited before (that was referred to 35 °C and 50%).

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