Cost-effective MEP solutions for a Passivhaus multi-family building in Mediterranean climate

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Abstract. A compact integrated unit for heating, cooling and mechanical controlled ventilation as a perfect solution for a Passivhaus certified multi-family building in Southern Italy (warm climate). An individual application for each apartment helping the single customer to achieve an autonomous control of each thermal parameters, reducing cost and installation plant's complexity. The compact system consists of a heat pump capable of recovering the extraction air flow heat to transfer it to the renewal air flow and to a domestic hot water tank. The extraction and renewal flows, pass through a recovery heat exchanger with high efficiency, in order to maximize the energy performance of the whole unit. To cover peak loads, related to the climatic conditions and user behaviour, a split system unit is used for air conditioning by recirculate the internal air. The unit allows a thermal integration function, cooling and dehumidification. The treated supplementary air, is delivered to the rooms through a specific distribution and the internal unit is located in the ceiling in a central part of the flat. A control system permits the operation of both the units comparing the measured parameters to the required comfort set point.

Keywords. HRMV, ventilation, MEP, HVAC systems, indoor air quality, comfort, Passivhaus, NZEB, multifamily

1. Introduction

In 2021 Italian code will requires NZEB performances for every new building just like all the other European state members [1]. High efficiency buildings are already present nowadays in Southern Italy [2] [3], but the main obstacle to the diffusion of this level of performances is still its higher construction cost [4]. A cost-effective approach was the goal in this work of ours. A well-insulated building, with a thermal bridges free envelope and airtightness, need a radical change in the mechanical-electrical-plumbing (MEP) solution. First of all, we need mechanical ventilation in order to achieve indoor air quality. In building like this one, the thermal comfort can be achieved solely by post-heating or post-cooling the fresh air mass which is required to achieve sufficient indoor air quality conditions. Higher costs for the envelope but cheaper for the MEP is the target to meet. A compact integrated unit for heating, cooling and mechanical controlled ventilation is a perfect solution for a Passivhaus residential building.

2. Case study building

The building is the first multi-residential Passivhaus building in Southern Italy. It is located in Putignano (Bari) and has three levels and an amount of eight apartments. Design phase started in early 2016 and the building has been occupied since June 2018.
A cost-effective approach was the goal in this work of ours. Meeting the tough demands from the Passivhaus certification criteria without no higher costs than the usual approach, respecting easier national code limits, was the main obstacle.

For a building to be considered a Passive House, it must meet the following criteria [5]:

- The Space Heating Energy Demand is not to exceed 15 kWh/sqm/year (treated floor area). In climates where active cooling is needed, the Space Cooling Energy Demand requirement roughly matches the heat demand requirements above, with an additional allowance for dehumidification.
- The Renewable Primary Energy Demand, the total energy to be used for all domestic applications (heating, hot water and domestic electricity) must not exceed 60 kWh/sqm/year (treated floor area).
- In terms of Airtightness, a maximum of 0.6 air changes per hour at 50 Pascal pressure (ACH50), as verified with an onsite pressure test (in both pressurized and depressurized states).

The reinforced concrete frame building has an inner wall of clay hollow bricks (mm 300) and an external insulation in EPS (mm 160) with a U-value = 0.16 W/m2K. On the roof, the insulation layer in rock wool is 180 mm thick and the U value is 0.18 W/m2K. On the basement ceiling the rock wool layer is only 120 mm instead.

Double pane glazing windows have a $U_w$ installed value of 1.40 W/m²K and a solar transmittance $g$=0.65, moreover they are cheaper. On the North elevation only there are triple pane glazing ($U_w$ installed value of 1.10 W/m²K). 17 photovoltaic panels of 270 Wp each with a total area of approximately 27.03 sqm for a total of 4.6 kW peak are installed in order to satisfy an Italian code request, actually proportionally to the plant area of the building instead of a more appropriate energy demand value.

![Figure 1. South (left) and North elevation (right) of the building.](image)

### 3. Compact unit

The compact system consists in a heat pump capable of recovering the extraction air flow heat to transfer it to the renewal air flow and to a domestic hot water (DHW) tank. In winter conditions, the heat pump partially condensate the refrigerant on the thermal storage tank, to dispose the overheating of the refrigerant fluid, and then to complete the condensation on the fresh air flow heat exchanger. The extraction and renewal flows passing through a recovery heat exchanger with high efficiency, they maximize the energy performance of the whole unit.

An integrated management system guarantee a flexible behaviour: the air change rate as well as the fan speed and the desired indoor temperature are fully customizable, furthermore weekly scheduling, warnings and alarms can be set. The system is illustrated in Figure 1a. According to the conditioning of the indoor environment, the compact unit has four modes of operation, automatically managed by the control system, depending on the internal and external conditions of the building:

- passive heat recovery
- active heat recovery
- bypass
- active cooling
In the passive heat recovery mode the exhaust air coming from the environment and the outdoor air is introduced in the passive heat recovery exchange energy thorough the heat exchanger. The heat level of the fresh air at the outlet of the exchanger is already sufficient to meet the needs of the house, for which the compressor will not turn on. In this operation mode, the only absorptions of the device are due only to the operation of the fans, and the electric consumption amounted to some tens of Watts. In the active heat recovery conditions (Figure 1b) the heat level of the fresh air coming out from the counter flow heat exchanger is not enough to meet the needs of the house and it is necessary to activate the heat pump. The exhaust air at the outlet of the heat recovery, which contains still usable thermal energy, is then delivered to an heat air/refrigerant exchanger to evaporate the refrigerant fluid. The same fluid is then sent to the compressor, and then undergoes to heat transfer, before to the DHW tank and then to the inlet fresh air, by means of the condenser. The machine COP (Coefficient of Performance) is high and the electric power consumption in this operating mode is always included in a range between 300 and 500 W, depending on the fan flow rate.

During the mid-seasons, with indoor temperature higher than the outside, the free-cooling mode allows to introduce directly inside the external fresh air to achieve the comfort conditions in the indoor environment. The unit prevents the passage of fresh air in the passive heat recovery, injecting it directly into the room, with internal 100% by-pass. The exhaust air, after crossing the recovery, is ejected. In this operation mode the only energy absorptions of the unit is due to the fans, and it amounts to a few tens of Watts.

When the active cooling mode is required, the outside fresh air can pass through the heat exchanger to recovery energy from the exhaust air or, alternatively, make the bypass. It depends on the temperature of the external air. If the fresh air temperature is too high to meet the needs of cooling, the controller activates the compressor, the air releases some of its heat to the refrigerant fluid in the heat pump evaporator and it is then sent into the indoor environment.

After the evaporator, the refrigerant fluid is processed by the compressor and condensed in the tank for the DHW generation (total heat recovering). Any residual heat is then release to the exhaust air in the final condensing phase. Summer cooling, combined with the total heat recovery for the DHW
generation, allows to achieve higher EER, according to the double useful effect. Even in this operation mode, the maximum power consumption is approximately 500 W.

If the temperature of the fresh air coming out from the passive heat recovery is already sufficient for the indoor comfort conditions, the energy content still present in the exhaust air could be used to increase only the energy level of the DHW tank.

The refrigerant fluid evaporated by the exhaust air flow, is then sent to the compressor, and finally fully condensed in the coil inside tank. During winter this mode of operation allows to reduce the thermal regeneration time of the tank. The heating of the DHW tank can always be set as a priority, controlling the heat transfer rate to the fresh air through the condenser. At any case, the unit is equipped with an integrative electrical heater for the DHW generation of about 1500 W as a booster or to do the antilegionella mode. One of the strengths of the machine is represented by its reduced size: 0.54 sqm of floor.

**Figure 3.** Air distribution in the Apartment n. 8.

### 4. Split System

A split system unit is used for air conditioning by recirculate the internal air (secondary air) to cover peak loads (only few days in a year, according to the calculations), but mostly to solve temporary uncomfortable conditions resulting from improper user behaviours, like keeping windows open too much. This unit works on thermal integration function, cooling and dehumidification. The treated supplementary air is delivered to the rooms through a specific distribution. The internal unit is located under the ceiling in a central part of the building (fig. 3 and 4).

**Figure 4.** The split system external and internal unit
5. Air distribution
The air distribution system made of polyethylene certified pipes with internal diameter of 74 mm to reduce the air velocity and pressure losses in the channels. The delivery pipes have been also insulated with a flexible insulating polyethylene extruded tube with λ of 0.035 W/mK to avoid temperature reduction and condensation of the air in the external part of the tubes. A better balance of the distribution system (primary air) can be achieved thanks to the air collectors, also under the ceiling in the central part of the flat. Moreover, the fresh air is picked up and ejected in the façade (prevent the short-circuiting of flows) by 160 mm internal diameter insulated pipes. The recirculation (secondary air) coming from the split system is delivered in the building coupled with the primary air coming from the mechanical ventilation by a specific double nozzle.

6. Integrated Management System, Monitoring and Supervision
The management of the CompactP and of the split system is integrated. A supervision control unit allows direct setting of temperature, humidity and CO₂ set point and switch on the single units to reach the desired values. The sensors included in the Nilan CompactP are used as master control. An RS485 Modbus communication system manages the two air conditioning units, by involving the split system only if it is needed as an additional booster. The management system allows the acquisition of the main operating parameters (temperature, air quality, etc.), data collection and remote control via an Ethernet connection.

[Figure 5. Sample of the supervision control system]

7. Costs and Finance
This solution has been compared to a complete traditional solution for MEP in the same region, with heat pump and radiant floor as heating system and ducted air conditioning as cooling system for each apartment. Moreover, an additional MVHR also for each apartment, only to prevent internal mold and condensation. Our MEP solution is 16.3% cheaper.

It made possible to achieve a Passivhaus standard but also affordable selling price. Other choices have been made in order to minimize the additional cost for the envelope (both opaque and transparent) but traditional envelope is still 18.8% more expensive than ours. The apartments are on sale at 1.800,00 €/sqm, which is exactly the price of all the other apartments in the city for a new construction, even if they are really far in energy performance and internal comfort.
**Figure 6.** Main operation Parameters (Black: Set Point, Green: External Air, Red: Exhaust air, Light blue: Internal Humidity)

**Figure 7.** DHW Parameters (Violet: Top Sensor, Green: Bottom sensor)

**References**

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