On the Energy Performance Design of a Skilled Nursing Facility Building

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Contents

- detailed description of the building

- dynamic simulation for heating and cooling energy demands analysis

- first results of monitoring

- further developments
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The RELAXXI building

Location: Noale (a little town 20 km away from Venezia, Italy)

It hosts 160 elderly residents who require 24-hour special assistance and medical care.
The floor surface is about 7400 m² and the whole conditioned volume is 23700 m³.
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Indoor side: the rooms

Outdoor side: piping and PV (95 kWp)
The main characteristics of building envelope

<table>
<thead>
<tr>
<th>Category</th>
<th>Specification</th>
<th>U-Value [W/(m² K)]</th>
<th>Optical parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>SHGC [-]</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>τ_{\text{Vis}} [-]</td>
</tr>
<tr>
<td><strong>Opaque constructions</strong></td>
<td>Slab-on-grade floor</td>
<td>0.29</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>External wall</td>
<td>0.23</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Roof</td>
<td>0.18</td>
<td>-</td>
</tr>
<tr>
<td><strong>Windows</strong></td>
<td>Glass</td>
<td>0.6</td>
<td>0.43</td>
</tr>
<tr>
<td></td>
<td>Frame</td>
<td>1.3</td>
<td>-</td>
</tr>
</tbody>
</table>

The Italian requirements by law (new buildings):

- External wall: $U = 0.34$ W/(m² K)
- Roof: $U = 0.30$ W/(m² K)
- Window: $U = 2.2$ W/(m² K)
The HVAC system

Thermal production
2 multifunctional air-to-water heat pumps:
   Nominal cooling capacities: 340 kW and 235 kW with COP of 2.94 and 2.96, respectively
   Nominal heating capacities: 264 kW and 176 kW with COP of 2.96 and 3.24, respectively

4 Gas condensing boiler: to meet peak loads and for recovery purposes
Each floor is equipped with 4 VAV boxes, two per wing.

In winter, according to field surveys, VAV boxes supply into the room two levels of air flow rates scheduled as follows: 2700 m$^3$/h per VAV box during the day (6am to 10pm) and 600 m$^3$/h per VAV box during the night.
Heat exchangers in the air handling units of the West and East wings:

- Rotary air-to-air enthalpy wheels
- Heat recovery efficiency: sensible 71%, latent 65%

3 air handling units:

<table>
<thead>
<tr>
<th></th>
<th>Supply Air Flow Rate [m³/h]</th>
<th>Exhaust Air Flow Rate [m³/h]</th>
<th>Supply Fan Power [kW]</th>
<th>Return Fan Power [kW]</th>
</tr>
</thead>
<tbody>
<tr>
<td>East wing AHU</td>
<td>17000</td>
<td>15300</td>
<td>13.7</td>
<td>7.3</td>
</tr>
<tr>
<td>West wing AHU</td>
<td>13000</td>
<td>11700</td>
<td>9.5</td>
<td>5.5</td>
</tr>
<tr>
<td>Kitchen AHU</td>
<td>8000</td>
<td>-</td>
<td>3.7</td>
<td>-</td>
</tr>
</tbody>
</table>
HVAC terminal units: 4-pipe constant flow active chilled beams, with air induction ratio equal to 3

air flow rate for each room 11 l/s/pp
Why chilled beams?
Active chilled beams can be selected to provide large amounts of sensible cooling and for reducing primary airflow requirements.

→ Indoor comfort

→ Indoor dehumidification
The model

A detailed method based on dynamic building energy simulation program EnergyPlus

The dynamic behavior of building envelope and HVAC terminal units are evaluated

→ The calculated hourly building demands are used as input in an excel spreadsheet to get the Heat Pumps electrical energy consumptions
The following basic principles of thermal zoning were observed:

- Same setpoint temperatures
- Same window orientation
- Thermal zones have window area equal to the sum of the window areas of the pertaining rooms
- Thermal zones have floor area equal to the sum of the floor areas of the pertaining rooms
- Similar HVAC terminal units
- Similar internal loads

As a consequence, 57 thermal zones were considered.

Climatic data:

- TRY for standard energy demand assessment;
- Monitored data for comfort analysis
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ideal system
## Temperature setpoints values

<table>
<thead>
<tr>
<th></th>
<th>Locker Room</th>
<th>Patient Room</th>
<th>Church, Gym, Ambulatories, Dining, Living</th>
<th>Toilets</th>
<th>Office Room</th>
<th>Entrance Hall</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Heating setpoint temperature [°C]</strong></td>
<td>24</td>
<td>20</td>
<td>22</td>
<td>20</td>
<td>23</td>
<td>23</td>
</tr>
<tr>
<td><strong>Cooling setpoint temperature [°C]</strong></td>
<td>28</td>
<td>25</td>
<td>26</td>
<td>20</td>
<td>26</td>
<td>28</td>
</tr>
</tbody>
</table>

**Lights:**
- Patient rooms: 1.6 W/m², from 7:00 to 9:00, from 13:30 to 15:00 and from 20:30 to 21:00
- Toilets: 8.5 W/m², from 7:00 to 8:00, from 13:00 to 14:00, and from 21:00 to 22:00
- Kitchen: 12.5 W/m², from 7:00 to 16:00 and from 18:00 to 21:00
- Office: 9.4 W/m², from 9:00 to 13:00 and from 14:00 to 18:00
- Emergency lights: always on, 24 hours per day
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Model: ground floor
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Model: first floor
Simulations allow to evaluate heating or cooling according to the building demand when:

- heat pumps are always on (the obtained values are the \textbf{ideal} heating and cooling need of the building: these values don’t account for HVAC plant and multifunctional heat pumps efficiencies);

\[ \rightarrow \text{Energy Index } 33 \text{ kWh/(m}^2\text{ year)} \]

- heat pumps and HVAC plant efficiencies are considered
Hourly heating and cooling need of the building
Multifunctional heat pump demand
Indoor air temperatures for the assessment of comfort acceptability in case of heating/cooling always available (a) and heating and cooling available only in winter and summer (b), respectively.
Simulated vs. measured indoor air temperatures for different room (east and west wings)

the largest differences in room air temperatures are around 2 K
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FIELD MONITORING – TYPICAL WEST ROOM (44)

RH peak ~ 70%

Temperature

Relative Humidity

0 5 10 15 20 25 30
0 5 10 15 20 25 30
15/07/2013 16/07/2013 17/07/2013 18/07/2013 19/07/2013 20/07/2013 21/07/2013
first comparison of internal loads of measured lights and plugs against the simulated ones

Some electricity consumption peak values around 12:00, 13:00 and 15:00 are probably due to some kitchen equipment activation.

good correspondence in the comparison
Conclusions

- First detailed simulation results seem to highlight an intensive use of cooling equipment and critical electrical energy consumption even if the specific values of total energy demand are acceptable;

- measured indoor air temperatures seem to be in line with the design data
Next steps

Future simulations shall try to analyze the indoor air humidity variation and the IAQ.

The model to be used to assess the sensitivity of the system to various parameters related to controls (set points, dead bands) and operation, with a view to monitoring the performance on the field.
Next steps

The management of the HVAC system must be improved; the control system must to be optimized:
- active chilled beams network pumps;
- indoor air control;
- storage tank hysteresis…

It is necessary to add other HVAC variables to better understand how the HVAC system is functioning
Some **NEW** HVAC variables of the monitoring

- Active beam water flow
- Hot tank storage temperature
- Cold tank storage temperature
- Multifunctional heat pumps supply temperature
- Multifunctional heat pumps return temperature
- AHUs return air temperature
- AHUs supply air temperature
- AHUs fans motor frequency
Lessons learned!

- one of the 2 HP was not working during the whole year;

- only the water pumps for active beams are variable speed, but active beams valves are mainly closed;

- the air flow rate in the rooms is manually modified;

- primary air preheating and postheating are active during summer.
Thank you for your kind attention!

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