Quantification of the Cost of Oversizing Cooling Installations in a Case Study Under Construction in Vietnam

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Abstract

In countries where energy regulation is rather lax and young, the HVAC design team might lack the incentive to do a careful sizing of the heating and cooling loads in a building. Instead, predefined values in watts per square meter, generous “safety factors” or a combination of both are used. Oversizing of HVAC installations occurs more often than one would expect - upon site visits in Vietnam, installations with several chillers are observed running one chiller only. In such cases, oversizing did not necessarily translate into malfunctioning on site, for the building occupants felt no issues, as there is no difference in comfort between an oversized installation and a rightly sized one. However, such design practice will unquestionably end up in a higher capital investment, lower plant efficiency, higher energy and maintenance costs when compared to a more carefully designed installation.

It is difficult for the project manager to assess the gap between the necessary and installed power for several reasons, ranging from internal (team technical experience) to external (common industry practice). Hence, for most projects little to no action is taken in this regard. However, it would not be difficult to convince the investor if he is informed of the total cost of this problem. The main difficulty is related to the lack of signs of discontentment:

- The HVAC designer delivered a system that provides air conditioning as requested, and “better installing too much than not enough”.
- The building manager has no major problems running the system. If one chiller goes out of service, plenty of backup is available.
- The design team technical knowledge is insufficient to assess the issue, either because the team lacks experience, or because technical experience comes from analogous designs.
- No regulation is enforcing the reporting and benchmarking of the efficiencies of the cooling plant, or the general building consumption.

In this case study, the final HVAC plans from a local MEP designer were placed under the magnifier and benchmarked against calculation-based cooling load sizing. An IESVE model was created for this office building for that effect; dynamic thermal simulations helped assessing the reality of the sizing results.

These values were finally converted into capital cost, energy cost and maintenance cost, so that the connection between choice and cost is finally achieved.

Key Innovations

- Quantification on the impact of oversizing in a real project based on as-built plans

Introduction

The case study is a 24-storey tower with office spaces in the upper levels and retail in the podium. This building is LEED Gold certified for the office spaces; the assessed gross floor area is 39,000 m².

The developer hired a third party to do an external review of the MEP design and to perform thermal dynamic simulations for LEED energy assessment of the credit EA1 – Optimize Energy performance.

When looking at the plans and submitted specifications, suspicions arose concerning the design workflow: the internal gain values seemed to disregard the specifications from the electrical plans and the client’s directives - a first early indicator that the calculated loads were not being accurately sized. As an example, the report described 15 W/m² for lighting when LEED requested no more than 9 W/m².

Besides the table with the overview of the internal gains, no detailed information was made available concerning the zone cooling loads. Therefore the link between the internal gains and the HVAC sizing cannot be established.
Considering that there was an accurate thermal model at hand used to perform the LEED energy assessment, a parallel analysis was performed to do a thorough cross-check on these values. Cooling load calculations were used to estimate the cooling load at zone and building level. The dynamic simulations from LEED were helpful to estimate the amount of energy attributed to the loss of efficiency for the chiller plant due to oversizing.

With all the information at hand, a second design was created, from zone cooling loads to flows in the primary and secondary loops of the chiller plant.

Methods

The key element for this analysis was the full trust of the client, which requested, collected, and forwarded all the available information regarding the HVAC design. Without this, all the comparisons would be merely based on assumptions, which would hinder the quality of the conclusions drawn in this assessment. The list of information made available is the following:

- Architectural plans
- MEP plans, per floor and sections
- HVAC hydraulic and aeralic schemas
- HVAC specifications of the water and air handling elements.

The methodology was divided in six steps:

1. Cooling load calculation using the IESVE model for LEED, which defined the peak powers for:
   - Zone cooling
   - Outdoor air treatment cooling
   - Dehumidification cooling

2. Recalculation of the needed installed capacity for cooling, and resizing of chiller, cooling tower, pumps, fans, and fan-coil units at zone level and system level.

3. Estimation of the impact on the capital cost and subsequent maintenance cost.

4. Thermal dynamic simulation for the entire year using the same model, locating the building in Ho Chi Minh City, Vietnam, which defined:
   - Cooling energy demand
   - Air treatment energy demand
   - Auxiliary energy demand - fans, pumps, and lighting

5. Conversion of the lower inefficiency of the cooling installation due to oversizing into a yearly energy cost.

6. Evaluation of elements of secondary importance in the scope of HVAC design, such as make-up water tanks, transformer, and generators (only concerning the ones affected by the cooling installation).

Results

The results show a clear oversizing at all levels. It remains unknown what parameters were disregarded as there was not enough detailed information from the design team regarding the cooling load calculations.

The degree of oversizing is clear in the following figures:

- The chiller power was oversized in 50% of the required capacity
- The cooling towers were oversized in 125%
- The pumps and piping were oversized from 50% to 120%

Converting this into a cost in a 10-year period:

<table>
<thead>
<tr>
<th>Element</th>
<th>Cost (USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy Cost</td>
<td>$369,280</td>
</tr>
<tr>
<td>Maintenance</td>
<td>$360,662</td>
</tr>
<tr>
<td>Equipment Cost</td>
<td>$947,568</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$1,677,510</strong></td>
</tr>
</tbody>
</table>

The final value runs close to 1.6 million USD, or 40 usd/m².

Other elements would increase this value further but deemed too difficult to convert into a cost, namely:

- Oversized pipes, pumps, and ducts.
- Technical installations, especially chillers, pumps, transformers, and generators require oversized technical spaces, which impact the total gross floor area of the building.
- Pipes and ducts require larger clearances for shafts and ceiling clearances (the designer requested a ceiling clearance of 1.1 m for ductwork per floor)
- Larger cores reduce the net floor area of each floor, which in its turn reduces the net lettable value of the office spaces.

Conclusion

The oversizing is a problem that is difficult to identify, and even harder to quantify, but very real. In this case study, the estimation of 1.6 million USD, or 40 usd/m² is undervalued, as other cost affecting factors such as net floor area available for rent, cost of oversized technical spaces and ceiling clearance, are not quantified.

The prevention of oversizing is a fundamental step for more sustainable buildings, as the impact on energy is two-fold: reducing the installation and running costs of cooling plants allows for the difference to be shifted toward more sustainable solutions.

References

2. ASHRAE Fundamentals 2017, Chapter 18, “Nonresidential Cooling and Heating Load Calculations”