APPLICATION OF CFD SIMULATIONS FOR LOCATING OUTDOOR UNITS ON HIGH RISE TOWER
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ABSTRACT
The efficiency of an air conditioning system depends on the ability of ODU (Outdoor Unit) to deliver the required air flow rate that is needed for cooling the refrigerant. The case described in this paper involves solving an actual case wherein the occupants of a high rise building were facing an issue with ineffective cooling from their air conditioning system. The issue was traced back to ODUs (Outdoor Units) which were not able to provide sufficient air flow rate since it was located facing high winds. Different ODUs (Outdoor Units) were simulated for their efficiency under known conditions to arrive at the most suitable unit to provide sufficient air flow. CFD simulations were used to locate an appropriate location for the placement of ODUs. Focus during analysis of results was on the pressure distribution around the candidate ODU location. The suction and exhaust side of the ODU was identified and pressure difference between the exhaust and suction surface was quantified. By comparing the additional pressure head against design pressure head, magnitude of deterioration of fan performance was understood and these results helped in locating the ideal location for placing the ODUs (Outdoor Units).

INTRODUCTION
This study is based on an actual scenario wherein the occupants of high-rise building complained of ineffective cooling from the air conditioning system. The primary reason for ineffective cooling was traced back to the outdoor units (ODU) which was placed outside facing high winds. It was noticed that when wind direction is South-West as during peak summers, ODU fans are not able to deliver the required air flow rate for cooling the refrigerant. The current location of the ODU fans is such that the wind induced pressure difference between exhaust and fresh air side of the ODU is much more or comparable to the fan design head thereby decreasing the fan efficiency.

The methodology employed in the study involves modelling a single floor of the high-rise building considering only the external features of the building. Though the prevalent wind direction is South-West during summer, the study was carried out taking into consideration at least five different wind directions i.e. ‘S’, ‘SSW’, ‘SW’, ‘WSW’ and ‘W’ to ensure that the choice of ODU location is favourable for reasonable variations in wind direction.
Focus of CFD analysis is to quantify the pressure at the suction side and the discharge side and compare it with pressure jump claimed by ODU manufacturer.

**ODU PERFORMANCE IN HIGH WINDS**

**Performance of top discharge ODU under wind**

The service area houses a top discharge ODU with 6 HP capacity with suction through the front and the side panels. The top discharge with cowl is also modelled.

From Fig 3 the flow pattern for ODU exhaust and suction air is shown. It was observed that due to the location of the cowl, exhaust air gets completely diluted with ambient air and fresh air is available for suction.

**Performance of front discharge ODU under wind**

The same service area now houses the front discharge ODU with 3 HP capacity with suction side located behind the ODU and exhaust side in the front.

From the flow pattern of the ODU, it was noticed that some of the exhaust air gets sucked up by ODU due to very low discharge speed and low static discharge.

Quantitatively, the average suction pressure is 198.4 Pa and average discharge pressure is 214.4 Pa. Hence, we note that ODU fans needs to overcome 16 Pa pressure difference which it claims to be capable of.
It is estimated that 35% of the suction air is from the ODU discharge, which in turn causes heating up of service slab area.

Quantitatively the average suction pressure is 207.1 Pa and average discharge pressure is 208.6 Pa hence it was noted that the ODU fans needs to overcome 1.5 Pa which the fan is able to but not enough to push the heated air out of the service slab.

**Modelling and simulation of the grill**

A representative stack of 10 grills is modelled and meshed with the objective to estimate the pressure drop across the grill for a typical flow rate of 5 m/s. The pressure drop was to be non-dimensionalized for discharge coefficient $C_D$ so that pressure drop at any velocity can be estimated. Value of $C_D$ is then used in simulation of typical service slab to observe the effect of grill on ODU performance.

From the Fig above, the pressure drop of 105 Pa for 5 m/s is computed with $C_D$ calculated as 7.33. The grill region is modelled as porous zone and corresponding porosity value is assigned for generating grill effect.

**Effect of grill on top discharge ODU**

![Figure 9 – Pressure distribution in the presence of grill in top discharge ODU](image1)

From the pressure distribution plot generated, it is observed that a high pressure region exist ahead of the grill and the pressure inside the service slab also increases. It was also found that pressure on the suction panels of ODU was 214.1 Pa whereas pressure on discharge surface of ODU was 270 Pa. Thus, under high winds, ODU fans need to generate 55.9 Pa pressure rise which the fan is capable of. Therefore, we can conclude that the presence of grill reduces the margin on static pressure that was earlier available to us. Additionally, it was also found that hot exhaust air is vented out to ambient air and it does not get sucked in by the ODU itself.

**Effect of grill on the front discharge ODU**

![Figure 10 – Pressure distribution in the presence of grill in front discharge ODU](image2)

From the pressure distribution plot, it is seen that the grill creates a higher pressure line upstream with pressure inside the service slab increased by about 7 Pa. Pressure on the suction surface of ODU is 218.8 Pa whereas pressure on the discharge surface of ODU is 221.8 Pa. Like top discharge ODU, in the presence of grill front discharge ODU needs to overcome more pressure drop than without any grills. As noted earlier, the issue of recirculation of hot ODU exhaust existed and this issue gets further aggravated due to the presence of grill because it acts as a resistance to exhaust flow from ODU and does not allow it to mix with ambient air. Therefore, almost 65% of air sucked in is from the discharge of the ODU itself.
SELECTING OPTIMUM ODU LOCATION

Flow around typical floor is analyzed using 2D CFD simulation. Triangulation was made and extruded for one layer. The mesh generated had around 38,000 cells with good quality triangles with gradual increase in size. The simulations were carried out for a floor located at a height of 150 m from the ground. A total of 5 simulations were carried out for different wind direction which was prevalent during summer. Based on the Indian Meteorological data, average wind speed at 10 m height during summer was found to be 5 m/s and this was used to extrapolate the wind speed at a height of 150 m/s using log law for atmospheric boundary layer and the same was found to be 18 m/s.

From the flow pattern generated around the building, it is evident that a stagnation region is formed just ahead of the building and a wake region is formed which extends far behind it. Additionally, it was observed that at the corners of the building, the wind speeds increases up to 100 kmph.

The pressure distribution around the building is shown for different wind directions. Pressure distribution is the primary factor that would affect the performance of the ODU fan. It is seen that upstream pressure is about 200 Pa with pockets of low pressure zones.

The performance of ODU fans depend not only on the dynamic pressure existing on the exit plane but also on the suction side pressure.

Analysis of candidate location

<table>
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<tr>
<th></th>
<th>S</th>
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<th>WSW</th>
<th>W</th>
</tr>
</thead>
<tbody>
<tr>
<td>Side A</td>
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<td>-245.8 Pa</td>
<td>-20.3 Pa</td>
<td>-33.3 Pa</td>
<td>-30.8 Pa</td>
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<tr>
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<td>0.1 Pa</td>
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<td>-2.4 Pa</td>
<td>-6.1 Pa</td>
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Figure 11 – Mesh generated around the typical floor of the building

Figure 12 – Flow pattern around the building at a height of 150 meters

Figure 13 – Pressure distribution around the building at a height of 150 meters

Figure 14 – ODU location and pressure distribution for various locations on the left wing of the building
Figure 15 – ODU location and pressure distribution for various locations on the right wing of the building

From Fig 14 & 15, the pressure distribution experienced by 6 HP ODU is simulated under various wind directions and the results are tabulated above. From the data computed, it was concluded that it is beneficial to have the suction from side A and the exhaust directed towards side B.

**Analysis of stagnation zones**

From the simulation it was found that 14 HP ODU always remain under the wake region since the building layout is such that it forms a small volume cavity in which hot ODU exhaust air is being discharged. If the ODU exhaust air does not have enough momentum/static head then the entire cavity may go hot further deteriorating the ODU performance. Hence, further simulation was performed to check whether the ODU exhaust air overcomes the cavity and mixes with the ambient air.

<table>
<thead>
<tr>
<th></th>
<th>S</th>
<th>SSW</th>
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<td>0.4 Pa</td>
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<td>-6.9 Pa</td>
</tr>
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</table>

Figure 16 – Modified direction for ODU discharge

From the simulation it was found that the ODU discharge hits the corner of the building and splits into two streams which is not favourable. It was suggested to change the direction of the ODU in order the vent the hot exhaust air in the easterly direction in order to minimize the stacking effect.

**CONCLUSION**

From the various simulations carried out for this study, it was concluded that the 3 HP front discharge ODU suffer from recirculation of exhaust air inside the service area because of their low static head. This condition further increases the temperature inside the service slab leading to deterioration of ODU performance. Therefore, it was proposed that high static top discharge ODU is better suited for high wind conditions. This recommendation has been proven from CFD simulations where the hot exhaust air is thrown out into the ambient air and it does not recirculate back.

Further, it was seen that the presence of louvers deteriorate the performance of both front discharge ODU (by recirculation of hot discharge air) and top discharge ODU (by increasing the adverse head by 40 Pa) as it increases the static pressure needed to overcome by ODU (Outdoor Units). The study has been able to identify the physics that was behind the ODU non-performance in building 1 and the study recommends the use of 6 HP and 14 HP units of 78.4 Pa for building 2.

Additionally, all the ODU locations for ODU have been investigated based on prevailing wind direction in the summer and the suitable orientation of the ODU are also recommended. Also, re-orientation in the exhaust direction of the ODU was suggested in order to minimize the effect of thermal stacking.

**REFERENCES**