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Analysis of Air Handling Unit (AHU) Dataset for Energy Efficiency

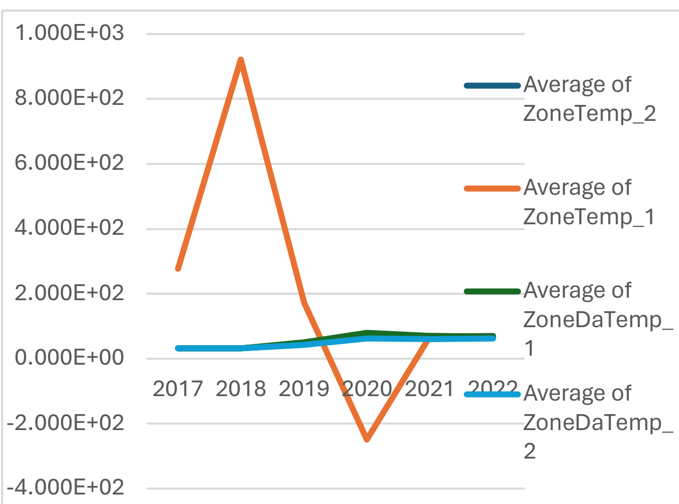
Maintaining optimal indoor environmental conditions and minimizing energy consumption relies heavily on the effective functioning of air handling units (AHUs). Examining and improving energy efficiency in AHU systems is essential for attaining sustainability and cost-effectiveness. AHU systems are components of commercial and industrial HVAC systems that regulate indoor air quality and temperature. However, their operation frequently accounts for a significant portion of a building's energy use. By analyzing the provided dataset, which contains a variety of operating characteristics such as temperature readings, fan power usage, valve positions, and damper settings, insights can be obtained into improving energy efficiency while maintaining comfort levels.

In this report, I present an analysis of an AHU dataset aimed at understanding energy consumption patterns and identifying opportunities for improvement. I will try to uncover the dataset's trends, patterns, and correlations to guide decisions in optimizing AHU control strategies. Through statistical analysis and visualization techniques, this report provides actionable insights for building management and energy conservation.

I. Temperature Dynamics

Analyzing temperature trends across different zones within the AHU dataset reveals crucial insights into the system's operational efficiency and potential areas for optimization. When examining temperature anomalies and inconsistencies in the data, it is important to consider the difficulties presented by the distinct features of the dataset. The identification and interpretation of temperature anomalies can be complicated by the lack of fault detection ground truth and the presence of data issues like missing features and inaccuracies. Hence, any discrepancies noticed should be handled carefully, and further actions may be needed to confirm the results and guarantee the analysis's credibility.

However, I will start by investigating some irregularities I found within the data; we can observe how the data for ZoneTemp_1 in 2019-2020 shows a spike down in average and intermittent instances of extremely low-temperature measurements mixed with average values at a closer look.



The location of the return air damper, which regulates the volume of return air that enters the air handling unit (AHU), may have contributed to the temperature problem. An insufficient amount of air circulation inside the system can result from the return air damper (RaDmpr) being closed or partially closed when it shouldn't be. This restriction may lead to temperature anomalies, such as abnormally low measurements, causing air to stagnate or become stuck.

When performing a correlation analysis on a sample of the data with RaDmprPos and ZoneTemp_1 where the irregularity is seen, the correlation coefficient becomes negative, which indicates a negative correlation between the RaDmprPos and ZoneTemp_1 variable. This means that as the RaDmprPos value increases (indicating more closure of the return air damper), the ZoneTemp_1 value decrease.

Row Labels	Average of ZoneTemp_2	Average of ZoneTemp_1	Average of ZoneDaTemp_1	Average of ZoneDaTemp_2
2017	3.200E+01	2.769E+02	3.200E+01	3.200E+01
2018	3.200E+01	9.213E+02	3.200E+01	3.200E+01
2019	4.519E+01	1.732E+02	5.086E+01	4.276E+01
2020	6.985E+01	-2.491E+02	7.973E+01	6.220E+01
2021	6.878E+01	6.979E+01	6.938E+01	5.955E+01

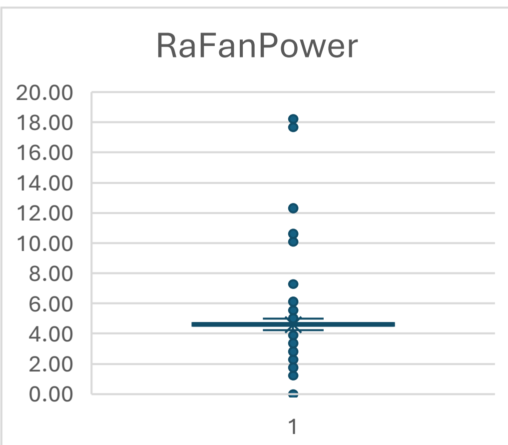
2022	6.976E+01	6.915E+01	6.779E+01	6.221E+01
Grand Total	5.580E+01	1.872E+02	5.803E+01	5.022E+01

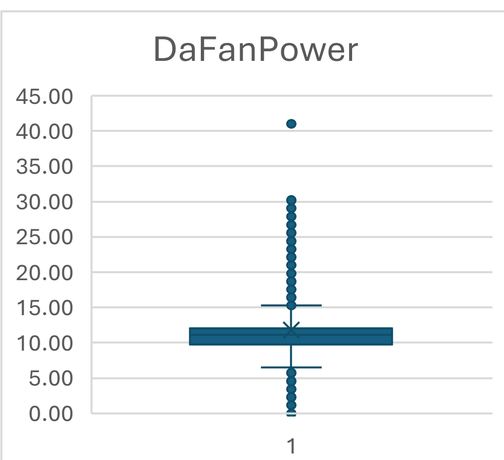
To move on to further statistical analysis of the data set, the mean temperature in ZoneDaTemp_1 is approximately 58.03 degrees, with a standard deviation of 23.91. In contrast, ZoneDaTemp_2 maintains a more stable temperature of around 50.22 degrees, with minimal variability. Such disparities in temperature distribution suggest potential inefficiencies in the heating and cooling processes of the AHU system.

To detect overheating and overcooling, we can examine temperature fluctuations in this dataset as potential indicators of overheating or overcooling in certain areas. Excessive running of the heating system may lead to overheating, which results in temperatures exceeding the comfort level. On the other hand, excessive cooling can lead to overcooling, wasting energy without adding any extra comfort.

What can be done? We can improve AHU operator's energy consumption by regularly monitoring temperature patterns and identifying zones prone to overheating or overcooling. For example, altering heating and cooling system setpoints based on real-time temperature data can help us maintain optimal comfort while reducing energy use. Furthermore, new control algorithms capable of predictive analysis can anticipate temperature swings and adapt HVAC operations in advance to avoid inefficiencies (Wang). Such proactive optimization tactics allow AHU systems to adjust dynamically to changing environmental conditions, ensuring energy-efficient operation while maintaining occupant comfort.

II. Fan Power





The mean fan power consumption for the discharge air side (DaFanPower) is approximately 11.79 units. This indicates the average power consumption required to operate the fan responsible for circulating air into the system. On the other hand, the mean fan power consumption for the return air side (RaFanPower) is approximately 4.59 units. This represents the average power consumption for the fan responsible for drawing air back into the AHU.

The standard deviation 3.51 for DaFanPower suggests a moderate variability in fan power consumption on the discharge air side. This variability indicates fluctuations in energy consumption, possibly due to changes in airflow demand or system inefficiencies. Similarly, the standard deviation of 0.81 for RaFanPower implies less variability in fan power consumption on the return air side than on the discharge air side.

The skewness and kurtosis values for DaFanPower and RaFanPower indicate the shape of the fan power consumption data distribution. Positive skewness and high kurtosis values suggest that the distribution may be skewed towards higher values with heavy tails, indicating potential outliers or extreme values in the data, which can also be demonstrated by the box and whisker diagrams.

III. Valve Positions

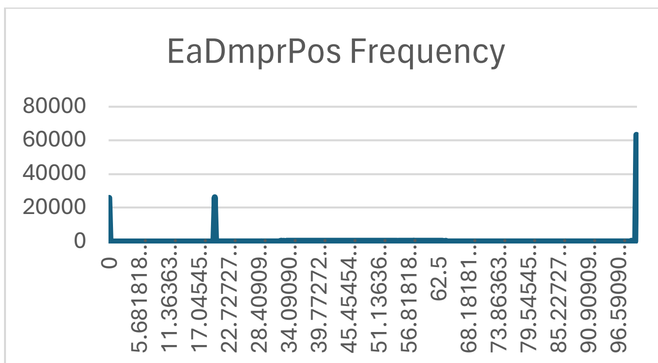
Analyzing valve positions through the provided data sheds light on their stability and variability. Valves such as ReHeatVlvPos_2 and HWVlvPos demonstrate minimal variability, with mean values of 0.96 and 2.56, respectively. This consistency suggests these valves operate within expected parameters, likely maintaining predetermined setpoints to optimize system performance. However, ChWVlvPos exhibits more variability, with a mean of 3.21 and a standard deviation 7.82. The fluctuations in ChWVlvPos imply variations in the chilled water flow, potentially leading to inefficiencies in cooling processes.

Optimizing valve positions presents an opportunity to enhance the efficiency of the AHU system by aligning energy consumption with demand. For valves like ReHeatVlvPos_2 and HWVlvPos, maintaining stable positions ensures consistent heating and reheat processes while minimizing energy wastage. In contrast, valves exhibiting higher variability, such as ChWVlvPos, indicate a need for improvement. By analyzing the factors contributing to fluctuations in valve positions, such as temperature differentials or load variations, operators can implement targeted adjustments to optimize valve operations (Koppenheffer).

IV. Damper Positions

Analyzing damper positions within the AHU system provides further insights into airflow regulation and potential areas for optimization.

Damper positions, including EaDmprPos (Exhaust Air Damper Position), OaDmprPos (Outside Air Damper Position), and RaDmprPos (Return Air Damper Position), exhibit variability. The mean positions for both EaDmprPos and OaDmprPos are approximately 57.90, with standard deviations of around 37.02. Similarly, RaDmprPos has a mean position of 34.75 with a standard deviation 34.64. These statistics indicate that adjustments in exhaust, outside, and return airflows are being made within the system.



However, the non-normal distributions observed in damper positions and potential outliers suggest it can be optimized. Kurtosis values close to -1.44 for both EaDmprPos and OaDmprPos and -1.34 for RaDmprPos suggest relatively flat distributions with tails shorter than those of a normal distribution. Skewness values close to -0.16 for EaDmprPos and OaDmprPos and 0.36 for RaDmprPos indicate a slight skew towards lower positions. In the chart above, we can see the negative direction in the kurtosis for EaDmprPos. These deviations from normality could signal irregularities in airflow regulation that may impact ventilation efficiency and indoor air quality.

By analyzing the factors contributing to non-normal distributions in damper positions, such as occupancy patterns or changes in outdoor conditions, operators can implement targeted adjustments to optimize damper operations. This could involve recalibrating damper settings based on real-time data or deploying advanced control algorithms capable of predictive analysis to anticipate airflow requirements and adjust damper positions accordingly (Chrysanthi).

Conclusion

Data analysis must be ongoing for well-informed decision-making and continued progress in energy efficiency within AHU systems. Through the implementation of proactive optimization solutions grounded in data analytics insights, we can set the stage for a more environmentally conscious and sustainable future in building management and energy conservation.

It is essential to tackle the hurdles presented by the distinct features of the dataset, such as the lack of fault detection reference, decreased detail, and different data problems, to create reliable fault detection and diagnosis methods for practical uses. Recognizing and conquering these obstacles allows researchers and practitioners to improve the efficiency and dependability of fault detection systems in industrial environments, resulting in better operational effectiveness and reduced expenses.

References

Chrysanthi, Sofia & Koulani, Mohammad & Hviid, Christian & Terkildsen, Søren. (2014). Optimized damper control of pressure and airflow in ventilation systems.

Koppenheffer, Roger, and Kevin Miller. "HVAC energy-saving strategies." *Consulting - Specifying Engineer*, 24 February 2020, https://www.csemag.com/articles/hvac-energy-saving-strategies/. Accessed 6 April 2024.

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