Parametric Analysis Toolkit for System Control

Case Study: One Montgomery Plaza

University of Pennsylvania

Introduction of the toolkit

The Parametric Analysis Toolkit for System Control developed by UPenn allows users to evaluate the impact of system control parameters on energy consumption for potential optimization. This toolkit uses a direct and rapid modeling method based on actual data. It avoids input configuration and calibration. It takes actual system operations into consideration.

The toolkit requires weather data, system sensor readings and metered energy consumption. The data should be monitored at least every hour. Hourly measured data including weather data, sensor readings and metered energy consumption are input into Gaussian Process to train a statistical model. After the data and model has been validated, users can select the system control parameters they want to investigate and assign a standard deviation to these parameters. Using the statistical model, the toolkit will calculate an impact factor that allows users to re-evaluate the system parameters. The impact factor is defined as,

$$\text{Impact factor:} \quad \frac{\text{Deviation of energy consumption caused by deviation of system control parameter(s)}}{\text{Energy consumption}} \times 100\%$$

The impact factor gives users an estimate of how significant the impact of the investigated parameter(s) is (are) on the overall energy consumption. Users can use this information to select parameters which have large impact to optimize.

The accuracy of the results rely on the quality of the data. The model robustness and data quality requirements need to be further studied in the future research.

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Data screening and preliminary analysis

The air handling units used in the building are dual-duct system. We take the data when only the cold deck is in use, which means there is no heating in the system. Therefore, data from June 3rd to September 16th is selected. We rule out the data-points during weekends and nights. Only the data-points on weekdays from 8 AM to 5 PM are used. We also filter the data-points when measured chiller power is below 50 kW.

Figure 1 to Figure 4 show the distribution of supply and return air temperature in the two air handling units in the building. The return air temperatures, which are close to the average zone temperature, show that sometimes the zones are over-cooled. The supply air temperatures spread from 46°F to 60°F, which might be caused by the inefficient control of chilled water supply. Since the range of AHU supply air temperatures is relatively wide, we want to investigate what their impacts are.

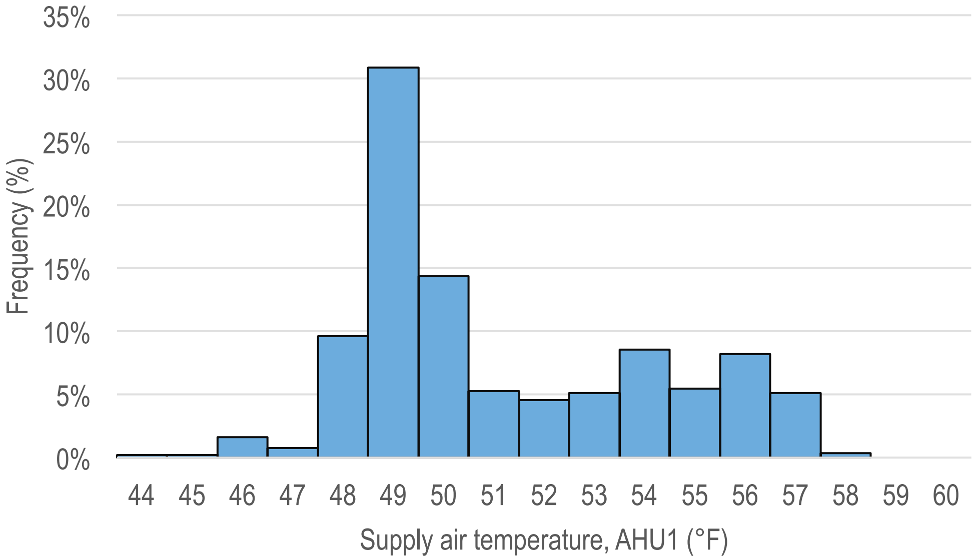

Figure 1 Histogram of AHU1 supply air temperature

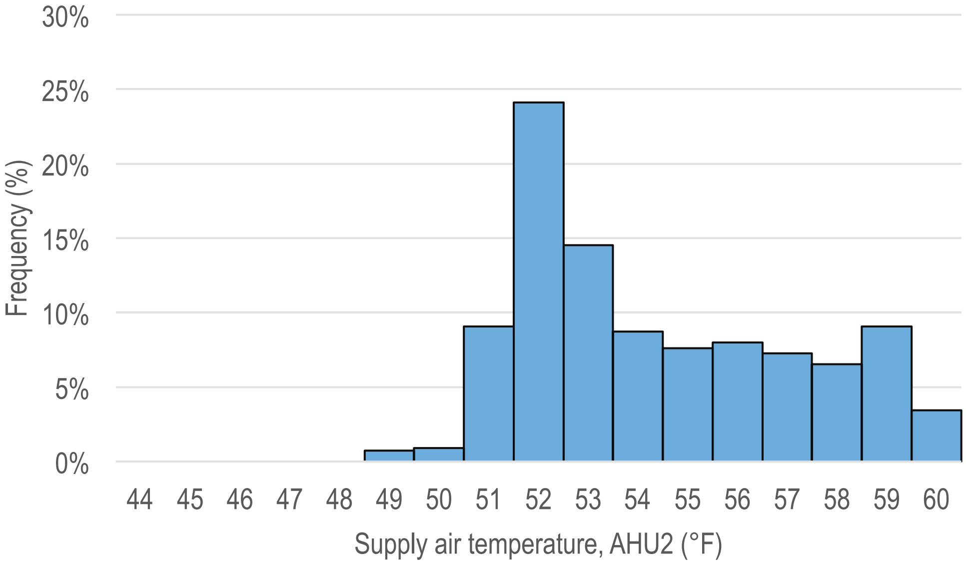

Figure 2 Histogram of AHU2 supply air temperature

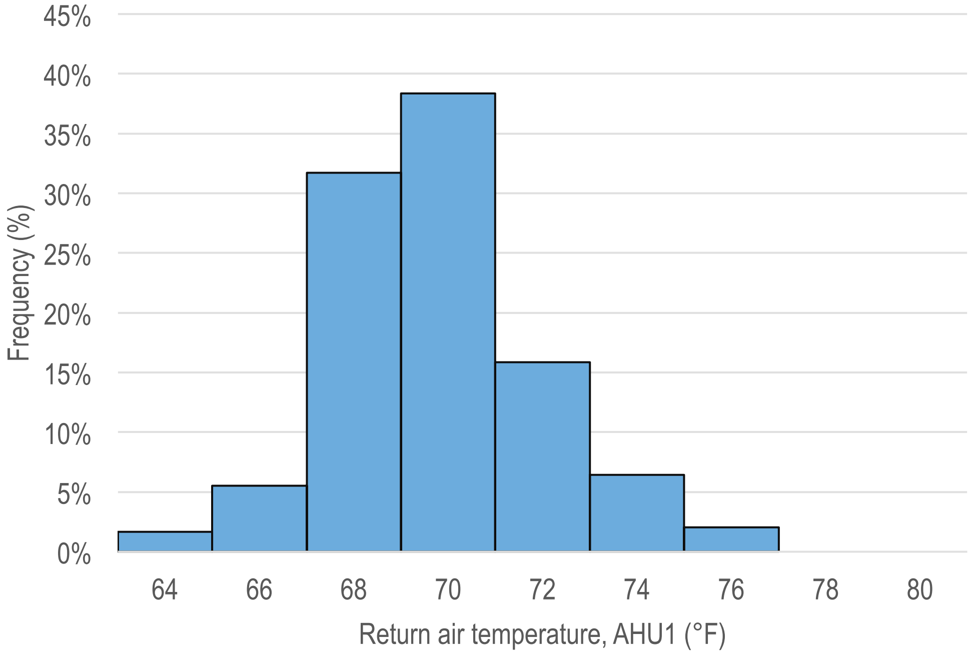

Figure 3 Histogram of AHU1 return air temperature

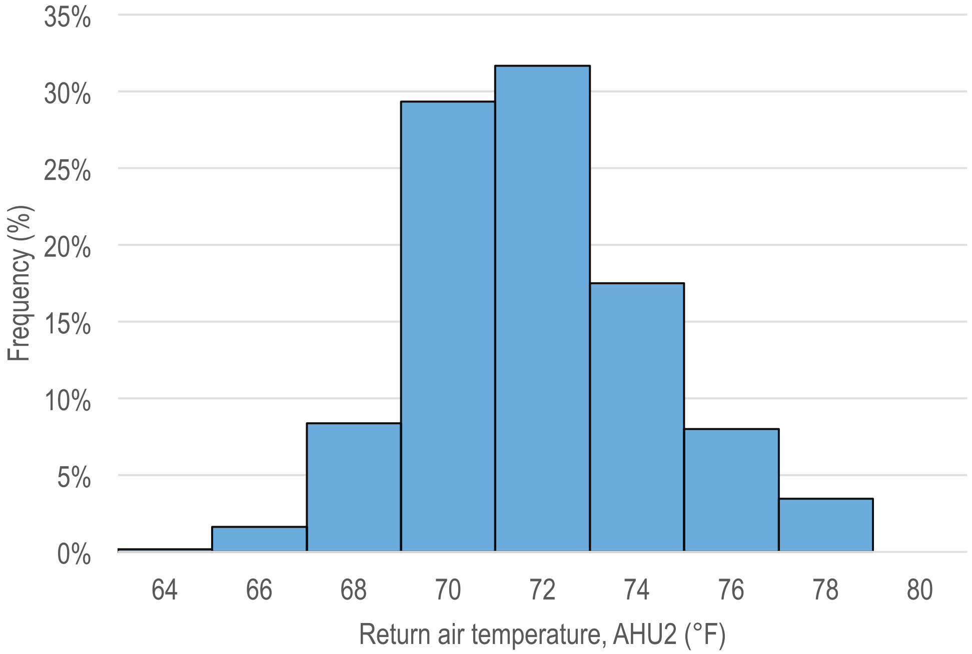

Figure 4 Histogram of AHU2 return air temperature

Model inputs

- Outside air temperature

- Outside air humidity
- AHU1 supply air temperature
- AHU2 supply air temperature
- AHU1 return air temperature *
- AHU2 return air temperature *

* Return air temperature depends on the supply air temperature, supply air volume and zone load. AHU return air temperature is correlated with supply air temperature. This correlation needs to be handled in the modeling. In the model, we use the difference between AHU return and supply air temperature as the actual input. Since the fan power is relatively constant, this temperature difference indicates the cooling load of the zones.

Model target

- Cooling electricity (electricity consumption for cooling), including chiller, cooling tower, chilled water pumps, cooling water pumps and AHU fans.

Model training

The training R^2 is 99.73%.

Results

The impact factors for cooling electricity and total electricity are calculated.

Impact factor for cooling electricity =

$$\frac{\text{Deviation of energy consumption caused by} \atop \text{deviation of AHU supply air temperature}}{\text{Cooling electricity}}$$

Impact factor for total electricity =

$$\frac{\text{Deviation of energy consumption caused by} \atop \text{deviation of AHU supply air temperature}}{\text{Total electricity}}$$

Investigated parameter(s)	Deviation (°F)	Impact factor	
		Cooling electricity	Total electricity
AHU1 supply air temperature AHU2 supply air temperature	2 2	19.81%	9.33%
AHU1 supply air temperature	2	16.22%	7.64%
AHU2 supply air temperature	2	9.82%	4.63%

We can interpret the results (first row data) in this way. Giving the observed data, if the weather and zone load stay the same, changing the AHU1 supply air temperature and AHU2 supply air temperature by 2°F could lead to 19.81% change in cooling electricity consumption, which corresponds to 9.33% change in building total electricity consumption.

AHU1 has a larger impact than AHU2, partly because its supply air volume is larger. Therefore, a change in supply air temperature will cause larger change in cooling consumption.

The conclusion above only applies to the summer conditions.