

CHILLER OPTIMAL SEQUENCING TOOL (CAN OPTI-COOL)



Context

Multi-chiller systems are commonly used in medium and large commercial and institutional buildings to provide cooling through chilled water systems. Instead of relying on a single large unit, these systems connect multiple chillers in parallel to ensure operational flexibility, redundancy, and scalable cooling capacity. This configuration allows the system to better match varying cooling loads throughout the day and across seasons.

Problem

Managing multiple chillers introduces complexity in operation. An efficient chiller sequencing strategy determines which combination of individual chillers to operate in order to satisfy a given building cooling load while minimizing the energy consumption of the whole cooling plant. This strategy involves assessing the performance of each chiller, as issues like poor maintenance, aging equipment, or suboptimal operating conditions can lead to inefficiencies. Optimal chiller sequencing – avoiding underperforming chiller combinations – can significantly enhance overall system efficiency and reduce electricity costs. An optimal chiller sequencing strategy should also consider when chillers are turned on or off to avoid unnecessary equipment switching which can accelerate equipment wear and tear.

Solution

CanmetENERGY in Varennes developed the Can Opti-Cool software to optimize multi-chiller plant sequencing using historical operational data. It uses measurements – such as compressor power, water flow rates, and temperatures – to build performance models for each chiller combination observed in the dataset. These models evaluate the cooling plant efficiency by considering the electric power demand of all equipment in operation (e.g., chiller, pumps, fans) and the cooling capacity delivered by the plant at that moment. Based on these models, control rules are determined to specify which chiller combinations to run at specific cooling loads to ensure high system-level energy efficiency while satisfying building cooling requirements.

Since this approach relies on historical data, it evaluates chiller combinations that have previously been in operation – no new configurations are generated. The optimization is based on past performance and cannot be used for design purposes, such as identifying new, theoretical combinations that might further improve system efficiency. This approach ensures ease of integration, as the configuration of the existing cooling plant does not require any modifications, while still achieving the highest possible overall efficiency and maintaining occupant comfort.

This strategy also aims to minimize frequent chiller cycling by introducing a cooling load deadband, which acts as a buffer zone to limit chiller combinations from switching on or off too frequently. By absorbing small fluctuations in load, it reduces wear and tear on equipment, extends lifespan, and enhances system stability. This cooling load deadband is achieved by specifying chiller combinations for increasing and decreasing loads, respectively.



Calculations

The cooling plant COP (Coefficient of Performance) corresponding to each timestamp in the dataset is calculated as the ratio of the cooling load delivered at that moment to the total electricity consumption of all equipment in operation at that time. The software automatically identifies combinations of chillers and ancillary equipment in use simultaneously by analyzing electricity consumption patterns in the input dataset – i.e., what equipment is on (consumes electricity) and when.

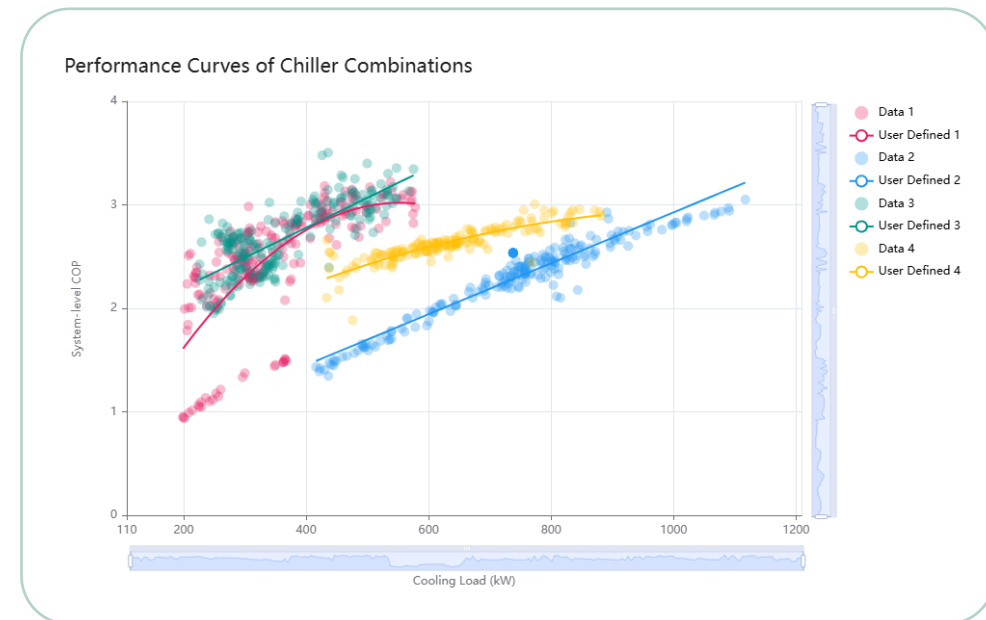


Figure 1: Performance Curves of Chiller Combinations

Once the chiller combination in operation at each timestamp is determined and the corresponding COP is calculated, the optimal chiller combinations corresponding to different cooling load ranges are determined.

Results

The calculations performed by the software and the results obtained are illustrated using a study that was performed to increase the energy efficiency of a large office building’s cooling plant – a 36,000 square meters, 11-storey building equipped with two 150-ton (527 kW) screw chillers and one 300-ton (1055 kW) centrifugal chiller. Operational data from the summer cooling season of 2023 was used in this study.

By mapping chiller combinations to defined load ranges, the approach guided users in selecting the best-performing configurations to maximize the overall efficiency of the cooling plant. To reduce excessive switching between chiller combinations, a deadband of $\pm 10\%$ is applied (+5% for increasing load and -5% for decreasing load) to ensure fewer changes in chiller combinations and minimize wear and tear on the equipment by avoiding frequent changes in configuration due to minor fluctuations in cooling load. The optimal sequencing rules indicate that, for increasing loads, 3 unique chiller combinations should be operated within 3 distinct cooling load intervals in order to maximize cooling plant efficiency; for increasing loads, the rules specify that:

- Combination #3, consisting of chiller 2 alone, is prioritized at low loads.
- Combination #4, consisting of chiller 2 and chiller 3, operate at medium loads inferior to 932 kW.
- Combination #2, consisting of chiller 1, should be engaged at high loads for its high nominal capacity.

The sequencing rules for increasing loads are shown in the following figure.

For additional information please contact
canmetenergy-canmetenergie@nrcan-rncan.gc.ca

Optimal Combinations

		Increasing Load	Decreasing Load
Combination ID		Cooling Load Interval kW	
3		<=642.6	
Related Equipment(s)			
Variable Name	Minimum Period Unit : hour	Nominal Chiller Ca Unit : Kw	Minimum Operati Unit : Kw
p_chiller2	1	527	26.35
4]642.6 , 932.0]	
Related Equipment(s)			
Variable Name	Minimum Period Unit : hour	Nominal Chiller Ca Unit : Kw	Minimum Operati Unit : Kw
p_chiller2	1	527	26.35
p_chiller3	1	527	26.35
2]932.0 , 1173.1]	
Related Equipment(s)			
Variable Name	Minimum Period Unit : hour	Nominal Chiller Ca Unit : Kw	Minimum Operati Unit : Kw
p_chiller1	1	1055	52.75

Figure 2: Sequencing rules for decreasing loads

Key Takeaways

- A comprehensive analysis of operational measurements is needed to evaluate cooling plant performance at different load conditions to identify the most energy-efficient chiller combinations.
- The Can-OptiCool software automatically determines an optimal chiller sequencing strategy to ensure that a cooling plant equipped with multiple chillers operates at a high overall efficiency while maintaining occupant comfort.
- Can-OptiCool defines clear operational rules for an existing cooling plant, enabling easy integration with the building’s control infrastructure.

