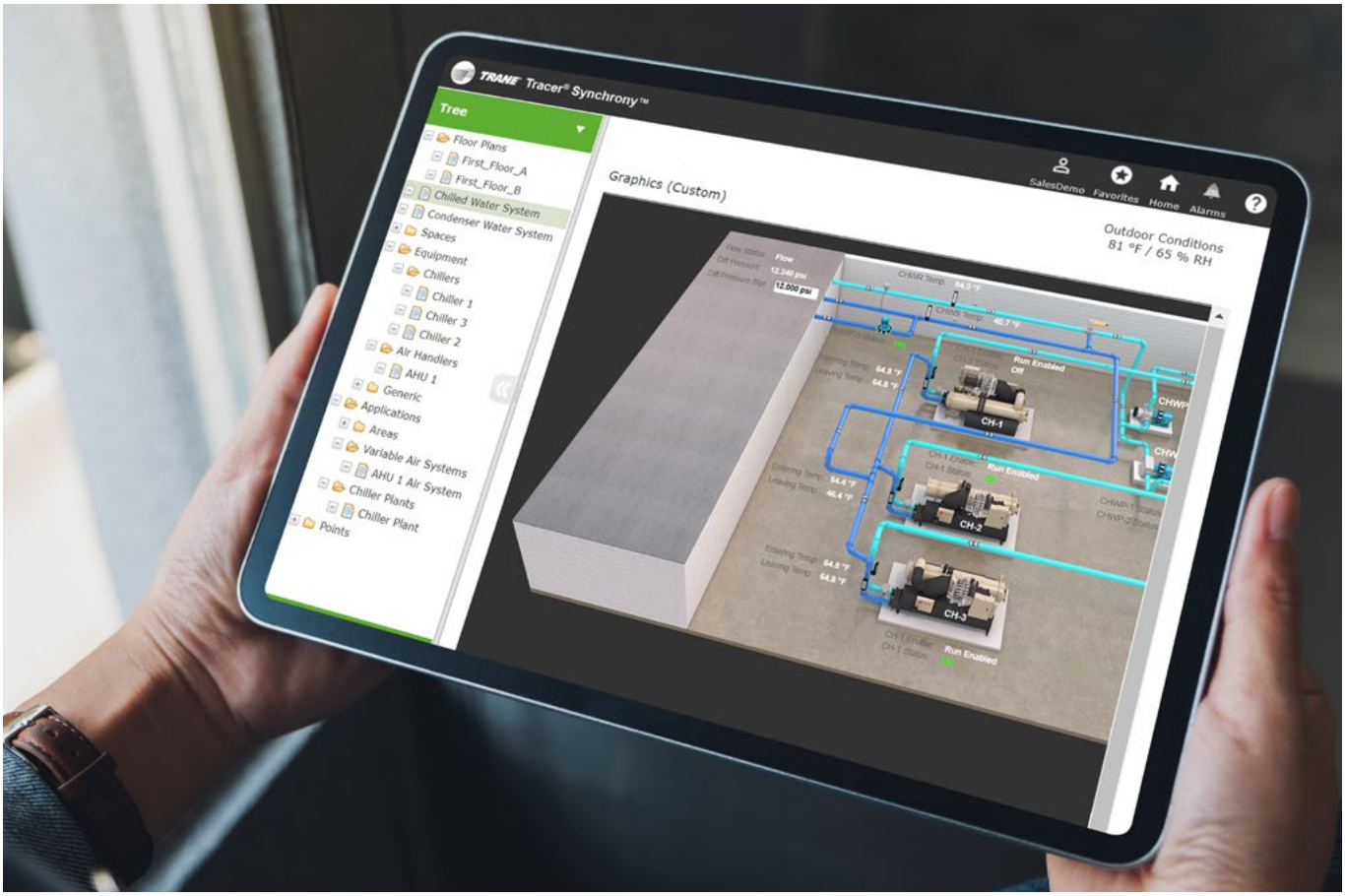
Chiller Plant Control for Data Centers



In today's technology-driven world powered by the Internet of Things and enabled by AI high computing, the need for strategic, reliable, efficient, and accurate chiller plant control is critical to the thermal management of data center IT infrastructure.

Though there are many ways to control chiller plants for these applications, a balanced approach is needed to ensure that these critical cooling systems operate at their peak level of performance and reliability as part of the system, while also considering the impact of equipment wear and tear, along with utility cost considerations.

Reliability and Stability

Reliable, stable facility operation is critical in these environments. With proper system design and redundancy, significant reliability and stability can be achieved. When properly controlled, facility reliability is further enhanced. Staging on the appropriate number of chillers to match the system load, while also preventing short cycling of equipment, not only maintains proper loop cooling capacity to match the load, but also reduces equipment wear and tear, thus improving overall equipment lifespan and facility reliability.



Trane TCAA Air-Cooled Oil-Free Magnetic Bearing Chiller

Compressor Short Cycling

Facility operation and control in an optimized manner prevents excessive compressor starts. With an excess number of chillers enabled, there exists a potential for multiple compressors to start and stop, attempting to maintain loop load. When loop load increases in excess of the currently operating compressor running capacities, any compressor in any of the run-enabled chillers could start to maintain the chiller leaving water temperature setpoints of the running chillers. If a chiller determines that there's a need to start an additional compressor, any of the other run-enabled chillers could also make the same determination to start an additional compressor. This may result in excess running capacity that overshoots the actual system loop load.

As a result, any of the running chillers starting an additional compressor could see a reduction in system load from this excess compressor running capacity, then determine that a compressor stage needs to be subtracted. The resulting behavior could be that multiple chillers short-cycle compressors, resulting in compressor and equipment damage, as well as poor loop temperature control.

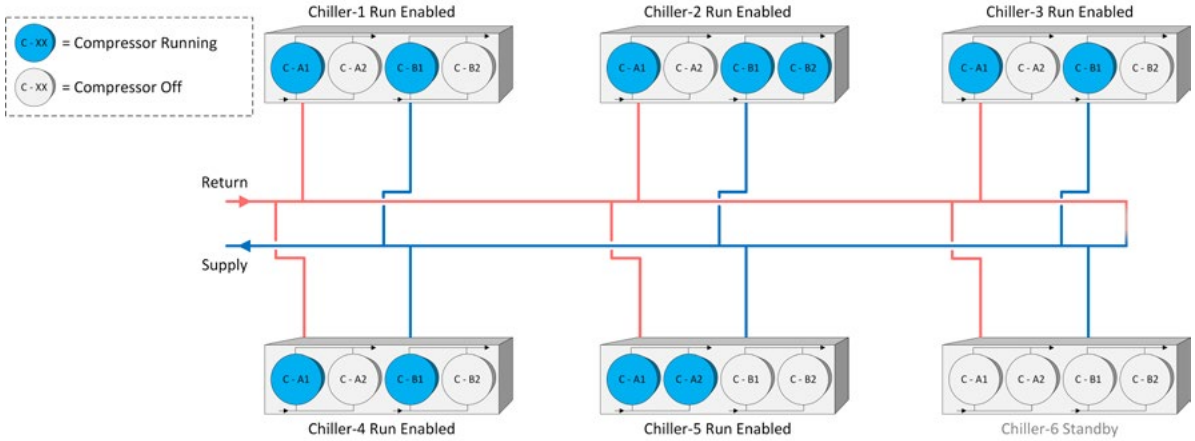
Energy

Short cycling of compressors, running excessive chillers over the actual system load, excess flow required for pumping, and excess staging up and down of facility chillers and compressors, can eventually result in excess energy usage. Ideally, the enabled chiller quantity and capacities should match the system load and operate in a reliable, stable and energy efficient manner. Staging on the appropriate number of chillers, while having the proper standby or available chiller capacity quickly available, results in lower energy utilization, reduced equipment wear and tear, more accurate loop temperature control, and a stable, reliable chiller plant operating to match system load requirements.

EXAMPLE

Consider a colocation data center facility with 6 chillers. The rated capacity of these chillers is 300 tons (1055 kW). Each chiller has 4 compressors across 2 refrigeration circuits with a compressor capacity of 75 tons (263.7 kW). The base loop load in this example is 825 tons (2901.4 kW). Given this loop load and capacity, the loop load is equivalent to running 11 compressors. This would be the equivalent of running 3 chillers with a standby compressor capacity of the remaining non-running compressor of 75 tons (263.7 kW).

However, if a facility has 5 chillers running, as shown in figure 1 below, there are 9 extra compressors ready to be used if needed. When the cooling demand goes above 825 tons (2901.4 kW), chillers 1-5 in the image below, the chillers might try to start these extra compressors to handle the increased load. Sometimes, more than one chiller might start an extra compressor at the same time. This can lead to having more cooling capacity than needed, causing some compressors to shut down and then start up again later. This frequent starting and stopping can affect the overall efficiency, temperature control, energy use, and reliability of the system.



Proper staging and control are critical to stable, reliable and efficient facility operation. This mitigates excess unit and compressor short cycling, that can potentially lead to compressor and equipment failures, as well as poor loop temperature and loop load control.

Efficiency

In addition to these strategies, optimal system efficiency is key to maintaining uptime in a data center, and meeting site energy goals and metrics. Staging and controlling chillers to properly match the system loop load, can and should factor the efficiency implications of the cooling system as a whole. Staging chillers at the proper efficiency and load points, based on efficiency curves, as well as staging chillers off at the proper efficiency points, results in lower energy utilization for the entire plant. The efficiency of variable capacity chillers is generally non-linear and dependent upon the load of the chiller and operating conditions. Typically, maximum efficiency occurs at part-load operation. Using known data about how efficiently chillers operate, a good staging system will decide when to turn a chiller on or off to make the whole facility run more efficiently. By doing this, the system can save energy and money by making sure chillers are turned on or off at the right times, while also keeping the loop temperature under control.

Performance

With the above strategies in mind, optimal performance can be achieved. Maintaining the correct number of operating chillers and appropriate sequencing allows for an environment that achieves maximum cooling while preventing short cycling damage to equipment. A proper staging strategy also balances equipment runtime and optimizes productivity.

User Diagnostic Indications and Failure Response

When problems occur with facility components, loop flows, chiller operation, or other rare issues, it is crucial to have accurate diagnostics and clear user alerts. Failure of a valve or actuator, chiller components or loop pumps are critical issues for plant operation. Ensuring that these and other critical conditions are monitored and users properly notified in a fail/fault state, is key to high reliability plant operation. On top of these concerns, the ability to quickly start another pump, chiller or system is critical to plant operation. A proper plant staging application response is critical to maintaining this required reliability and plant performance.

Service of equipment and system related components is also critical to plant operation. The ability to easily make a chiller unavailable to the staging lineup while also not impacting plant staging operation calculations is key. And likewise, once completed with service or repairs, the ability to easily bring the chiller or equipment back into the staging lineup and reset any alarms or failure diagnostics is also of great importance to plant operation and control.

Summary

As the demand for data center high computing to enable AI grows, so does heat rejection. An integrated thermal management cooling strategy is important to protect uptime and manage operational costs. There are various approaches to control and operate chiller plants as part of a system. Careful consideration and application of these strategies outlined is vital to an optimized data center thermal management strategy. Without proper staging and sequencing of chiller plant control, system cooling reliability, performance, efficiency, operation, equipment lifespan and productivity are negatively impacted.

About the Author

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Dan Berg is a Trane Controls System Applications Engineer with 18 years of field experience in HVAC, process cooling, chillers, and data center and commercial/industrial controls. He has a passion for designing control system architectures and developing unique and innovative solutions for chiller plant control, system controls, and redundancy controls for data center applications.

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DC-WPR003A-EN
09/16/2025