General Services Administration
Public Buildings Service

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CONTROL OPTIMIZATION SYSTEM FOR CHILLER PLANTS

Simplified Chilled Water System Optimization Increases Plant Efficiency

Chiller plants, the dominant source of space conditioning for commercial buildings with more than 200,000 ft^2 of floor space, are arguably the unsung heroes of occupant comfort. Still, conventional chillers are typically designed to run most efficiently at peak loads, when, in reality, peak load conditions are rare. For this reason, and because over 80% of GSA floor space is in large buildings, GSA has a keen interest in optimizing its chiller operations. A new technology, a control optimization system for chiller plants, aims to improve chiller plant efficiency at part load and to minimize total power consumption in two ways: by aligning pressure and temperature setpoints with real-time system dynamics and by controlling pump and fan speeds. In 2013, GSA's GPG program commissioned the Department of Energy's Pacific Northwest National Laboratory (PNNL) to assess the control optimization system under real-world conditions at the Frank M. Johnson Jr. Federal Building and U.S. Courthouse in Montgomery, Alabama. Comparing the technology's performance with an estimated baseline, researchers found a 35% energy savings and payback of five years, assuming a national average energy rate of $0.11/kWh.

The GPG program enables GSA to make sound investment decisions in next generation building technologies based on their real world performance.

INTRODUCTION

"We chose this technology to meet ventilation code requirements and provide cooling in winter and shoulder months. It not only solved our problems, it simplified operations and increased our overall plant efficiency."

— Mark Moody, P.E., C.E.M.
Mechanical Engineer
Atlanta, Georgia
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TECHNOLOGY SPECIFICATIONS
Control Plant Optimization System

- VFDs required on all pumps and fans
- VFD not required on chiller compressor motors
- One chilled water loop, no bypass water
- Variable speed pumping on both chilled and condenser water flow
- Optimizes pressure and temperature setpoints based on current system dynamics
- Allows for lead/lag chiller sequencing
- Customizable control algorithms
- Chiller agnostic and can be implemented without voiding equipment warranties
- Submeters all chilled water systems including chillers, pumps, towers and AHUs

What Is This Technology?

A HOLISTIC APPROACH TO CHILLER OPTIMIZATION

The control optimization system controls the operation of both water-cooled centrifugal and screw-type chilled water plants. It optimizes performance holistically, by monitoring and controlling five interdependent systems: cooling towers; condenser pumps; chillers; chilled water pumps; and air-handling units. The system is tailored to match the unique design of the chiller plant in question and the building loads served. The technology helps maintain optimal differential system pressure, manages chiller lift by eliminating flow issues under part-load conditions, and increases deliverable tonnage. While it does not require costly variable frequency drives (VFDs) for chiller compressor motors, the control strategy does require VFDs on all ancillary components (chilled-water primary and secondary pump motor, condenser-water pump motors, and cooling tower fan motors) to achieve part-load efficiencies. Achieving the technology's maximum benefit might also require piping and valve changes (3-way to 2-way), depending on the existing system's vintage and design. The system is chiller-brand agnostic and compatible with most BACnet-based building automation systems (BAS). The technology can be installed as a retrofit without voiding equipment warranties and is also suitable for major renovations and new construction.

What We Did

INSTALLATION INCLUDED SENSORS AND VFDS ON ANCILLARY SYSTEMS

The test facility for the control optimization system consists of two buildings: the historic 135,000 ft^2 Frank M. Johnson Jr. U.S. Courthouse, and the more contemporary 325,000 ft^2 Frank M. Johnson Jr. Federal Building, also known as the "annex." The courthouse and annex share a central chiller plant with three, 400-ton constant-speed centrifugal chillers. In 2012, GSA installed the control optimization system to improve chiller plant operations and provide cooling in winter and shoulder months. Before installing the system, the chillers were not able to run at the low part-loads required during cooler months. The installation included additional flow sensors, pressure-differential transducers, and VFDs on the pumping system and cooling tower fans.

In 2013, GPG commissioned PNNL to assess the performance of the control optimization system. In order to determine the energy and cost savings associated with the control technology, as well as the thermal cooling load profile, researchers monitored total chilled-water plant input power, chilled-water flow rate and supply and return temperatures, and the electric energy consumed by the chillers, chilled- and condenser-water pumps, and cooling tower fans. Monitoring occurred between January 13th and August 31st, 2013, and included peak summer and shoulder season load periods. Because the control optimization system was installed before this assessment was planned, and because no baseline was established prior to installation, performance was compared to an "estimated" baseline that was developed by operating and monitoring the chiller plant in "manual mode" for two separate two-week periods.

FINDINGS

35% COOLING ENERGY SAVINGS The average chiller plant efficiency throughout the demonstration was 0.64 kW/ton. This resulted in cooling savings of 523.44 MWh/yr or 35%. **Note:** Due to the limited data set from the brief "manual mode" baseline period, researchers report a confidence level in the projected savings of 80%, resulting in a total uncertainty of +/- 10%.

FIVE-YEAR AVERAGE PAYBACK Assuming 35% energy savings and the local utility rate of $0.08/kWh, annual savings were $42,485. Based on the installed cost of $310,000 at the Frank Johnson Federal Building, payback is seven years. At the national average utility rate of $0.11/kWh, annual savings increase to $57,530 and payback is five years.

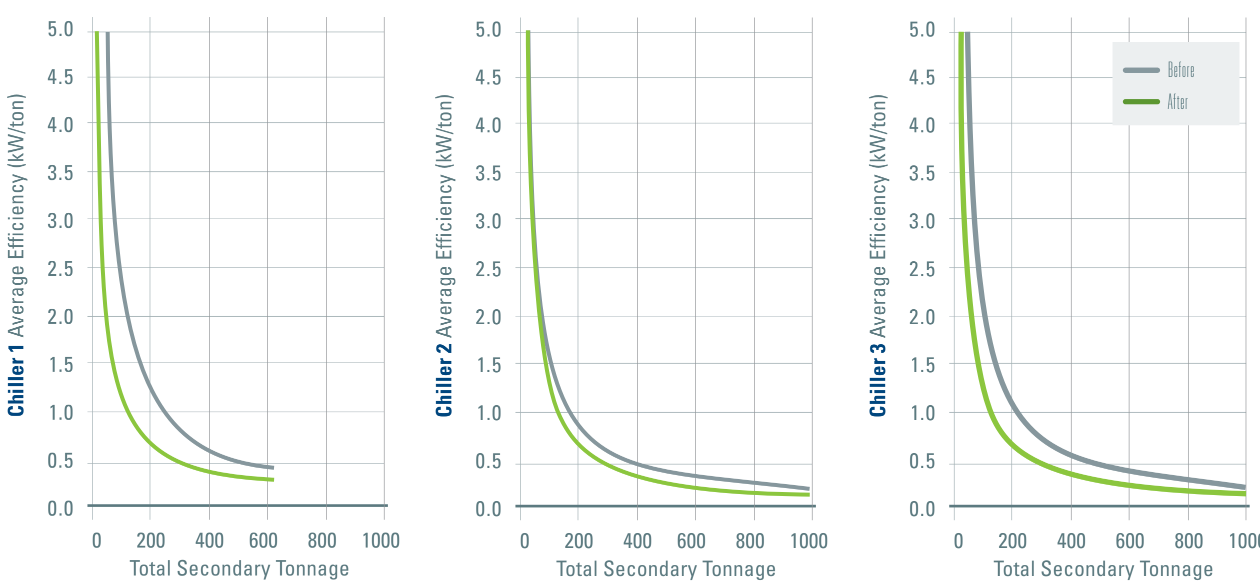
IMPROVED PART-LOAD EFFICIENCY AND DELTA T During part-load conditions, which occur most of the time, hydronic coils typically function at a lower Delta T than is specified by system design. This results in the pumping of more water than would otherwise be necessary to heat or cool the air. In general, the minimum Delta T for hydronic coils should be 8°F. Delta T for the chillers with the control optimization system ranged between 8°F and 18°F, and even during part-load conditions they consistently operated with a Delta T above 10°F.

ENHANCED SYSTEM OPERATION The technology provides greater visibility into plant operations. For example, during the assessment, building staff noticed that two chillers operating with similar loads had very different efficiencies. This led to the discovery of a faulty bearing in a cooling tower fan. Staff were able to replace the bearing before the fan failed.

CONSIDER FOR CENTRIFUGAL CHILLED WATER PLANTS WITH LOADS > 3 MILLION TON-HRS/YR*
Cost-effectiveness is related to facilities' annual ton hours and energy costs. For energy costs at or above the national average of $0.11/kWh, cooling loads greater than 3 million ton-hours per year are recommended. For energy rates below the national average, cooling loads greater than 4 million ton-hours per year are recommended. The technology is not as likely to be cost-effective for screw chiller plants or facilities with a cooling season of less than six months.

Increased Efficiency, Especially at Part Loads

Performance averaged 0.64 kW/ton after control optimization



CONCLUSIONS

These Findings are based on the report, "Optimization of Variable Speed Chiller Plants: Frank M. Johnson Jr. Federal Building and U.S. Courthouse, Montgomery, Alabama," which is available from the GPG program website, www.gsa.gov/gpg

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What We Concluded

OPTIMIZATION WITHOUT THE NEED FOR A VARIABLE SPEED CHILLER

Although chiller plants are essential to cooling the majority of GSA's large commercial buildings, few of them operate as efficiently as they were designed to. Analysis of data collected during this assessment shows that the control optimization system for chiller plants technology goes a long way toward solving this problem. Control optimization automatically controls and sequences the operation of the entire chilled water plant to increase overall efficiency, not just the efficiency of a single component. This is particularly true of operation at part load; in the current evaluation with a 1,200-ton plant, loads < 500 tons showed the greatest improvement. Further differentiating the control optimization technology studied here from other technologies of its kind is the fact that the chiller itself does not require a variable frequency drive; VFDs are required only on ancillary system components. By providing submetering, trending data, and information on average performance in kW/ton, the technology also increases visibility into plant operations.

If the control optimization system for chiller plants were installed throughout GSA's portfolio, energy savings of 20% to 50% would result, yielding annual cost savings between \$5 million and \$13 million. This technology is recommended as a retrofit for centrifugal chilled water plants with cooling loads greater than 3 million ton-hours per year. It should also be considered for incorporation into new all-variable-speed chiller plants. In this case, the manufacturer estimates savings of between 20% and 30%, but system costs will be substantially lower.

WAYS TO FURTHER IMPROVE CHILLER PLANT PERFORMANCE

- **Cooling Tower Leaving Water Temperature (ECWT) Setpoint Reset** During cooler/dryer conditions, the ECWT can be lowered, which will reduce the refrigerant head pressure, thereby reducing the load on the compressor and raising the Coefficient of Performance (COP).
- **Chilled-Water Supply Temperature (ChWST) Setpoint Reset** Raising the chilled-water supply temperature will allow the evaporator refrigerant pressure to be increased, thereby reducing the load on the compressor and raising the COP. Automated resets should take into account true load conditions that reflect demand and help optimize chiller lift. It also is imperative that humidity sensors are accurately calibrated and maintained. If not done correctly, this strategy can transfer energy to air handlers across the building.
- **Improved Optimal Equipment Runtime** While other technologies seek to optimize chiller plants by running multiple components simultaneously, this technology seeks to optimize pumping power based on dynamic loads. Validate planned staging operations to ensure that maximum efficiency is realized.

Footnotes

*Subject to evaluation and approval by GSA-IT and Security.

Technology for test-bed measurement and verification provided by Siemens.