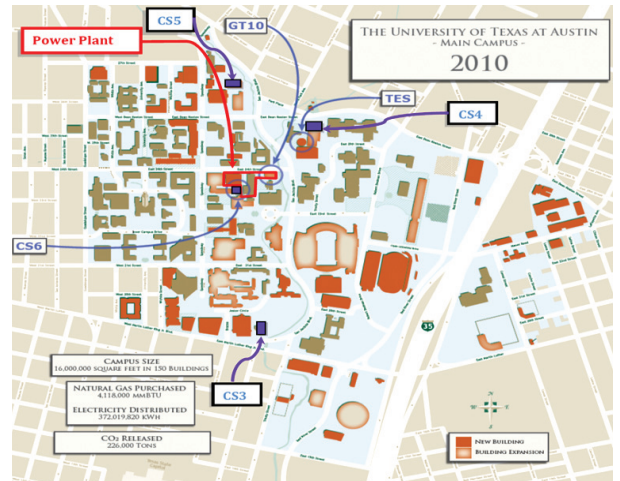


On the Cutting Edge

The first 15,000-ton, all-variable-frequency controlled chilling station

BY JUAN M. ONTIVEROS



Figures: Optimum Energy LLC

Figure 1: Location of University of Texas at Austin district energy plants

The University of Texas at Austin is a dense urban campus of more than 17 million square feet in 150 buildings, serving 70,000 students, faculty, and staff. The majority of the campus is research-oriented, operating 24 hours a day year-round, and requiring a variable and uninterrupted supply of energy. The campus is served from a combined heat and power (CHP) district energy system that includes 137 MW of onsite CHP, 1.2 million pounds per hour of steam generation, and 48,000 tons of chilled water capacity. A 4-million-gallon chilled water thermal energy storage system is scheduled to come online by September 2010.

Connections to the Texas electrical grid exist only for emergency backup, providing the University independence and versatility in generating 100% of the University's electricity, chilled water, and heating steam. The original lignite and fired boiler steam system was started in 1929, but was converted to natural gas in the 1930s. The system has since evolved to produce 350-million-kWh electricity, 980 million pounds of steam, and 136 million ton-hours of chilled water annually, with a distribution structure consisting of 6 miles of underground tunnels and more than 30 miles of underground electrical duct banks. The University's district energy system has had a reliability of 99.9998% over the last 35 years. As illustrated in Figure 1, the plants are located in the middle of the campus.

Since 1998, the campus has grown by approximately 8 million square feet. Meeting this space growth has been a challenge, and cooling needs, in particular, are an intense challenge, because the production of chilled water consumes approximately one-third of the energy produced by the CHP plant.

The central cooling plant system consists of four central plants with 45,000 tons of capacity tied into 6 miles of chilled water distribution system piping. The plants serve a peak load of 35,000 tons, and the annual chilled water production in 2009 was 146,000,000 ton-hours. In Austin, cooling is a big deal.

Like most universities, keeping up with equipment and

infrastructure needs in an environment where energy and space growth stretches budgets is a big challenge. To meet the challenge, the utilities organization has had to focus on efficiency improvement savings to pay for the infrastructure needs. Savings realized from efficiency improvements have paid for additional plant capacity, totaling 49 MW of additional power, 100,000 pounds per hour of additional steam, and 16,200 tons of new cooling capacity. Figure 2 shows the success over the last 12 years, with fuel use versus campus growth created by improved efficiency.

The focus of this article is the addition of a new, 15,000-ton, all-variable frequency drive chilling station. The University was faced with the major challenge of meeting the cooling needs of the campus, a fact validated by a chilled water system master plan study in 2005. The study indicated that the existing 40,800-ton plant was facing hydraulic limitations in the distribution system and was within a few years of exceeding available capacity.

Chilling Station 2 was the oldest plant, consisting of three steam turbine-driven chillers, totaling 7,800 tons. At 50 years old, it was inefficient and beyond its useful life. In addition, the plant was located in a prime campus location that was needed to expand the computer science department with a new building. All of these issues created a perfect storm that was also compounded by a need to construct the new 15,000-ton plant with a footprint no larger than the 7,800-ton plant it was replacing, and do it in a beginning-to-end project timeline of two years. The photo in Figure 3 indicates the challenge of building the new plant in a space-constrained campus.

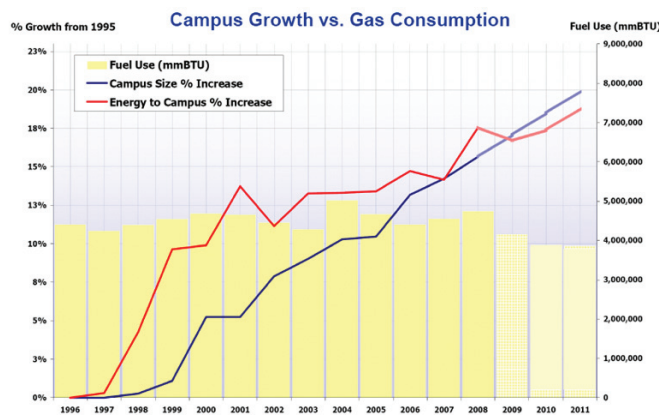


Figure 2: University of Texas at Austin campus growth versus gas consumption

Because of the time constraint, the project was implemented as a design-build project. The three 5,000-ton chillers had a fabrication period of one year, so it was necessary to select the design-build team and make the chiller selection up-front. The selection process was based on a 30-year life-cycle analysis that emphasized a total plant kilowatt-per-ton efficiency (not just the chiller), so that the facility design could begin immediately, and all of the other long-lead equipment could be expedited.



Figure 3: Location of old Chilling Station 2 and new Chilling Station 6 at University of Austin at Texas

In keeping with the culture of efficiency and savings, and to make the project more cost-effective, the following decisions were made:

- Install a 3,000-ton inlet air coil to serve our 45-MW combustion turbine and also provide chilled water from this station to the new 34-MW combustion turbine that was in construction. This boosts generation capacity and improves the plant heat rate.
- Use variable frequency drives (VFDs) to take advantage of the characteristics of these particular chillers, to not only improve the kilowatt-per-ton, wire-to-water efficiency with lower condenser water temperature, but also take advantage of the characteristic that kilowatt-per-ton efficiency is improved when the chiller is run at partial loads. Figure 4 demonstrates this effect.

This is an important issue because, while cooling plants need to be designed to handle peak loads, they are operated at part loads for the majority of the year. Therefore, any system that can operate efficiently at part loads is highly desirable. This is illustrated by the campus load profile in Figure 5.

- The decision was also made that all rotating equipment would have VFDs to capitalize on part-load conditions.
- No control valves would be used to modulate flow through the chiller evaporator or condenser to reduce pressure losses.
- Control valves would only be used to modulate the three cooling tower cells, so that flow could be balanced evenly.

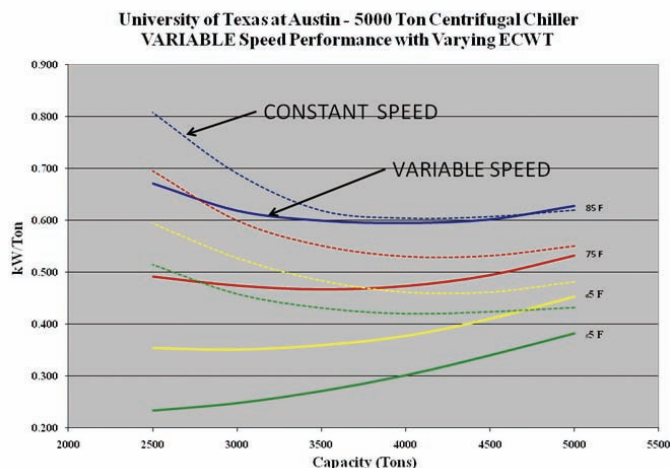


Figure 4: University of Texas at Austin variable speed performance with varying entering condenser water temperature

- OptimumLOOP software, part of the OptimumHVAC energy reduction software system from Optimum Energy, would be used to optimize operation of the chilling station for energy efficiency. This solution simply overlays the existing programmable logic controller controls, to automatically provide set points to all of the rotating equipment (chillers, chilled water, and condenser water pumps and cooling tower fans) in the plant, based on real-time load requirements, changing climate conditions that affects cooling tower effectiveness, and varying chilled-water distribution system pressure needs.

The expected outcome from this approach would be that:

- All online chillers would have identical flow and output through the evaporator.
- All online chillers would have identical flow through the condensers.
- Control valves on chillers would be line sized and open/close isolation only.
- Chilled water supply temperatures could be reset (raised) when outside temperatures, and thus, cooling loads were reduced in order to improve chiller lift and energy efficiency.

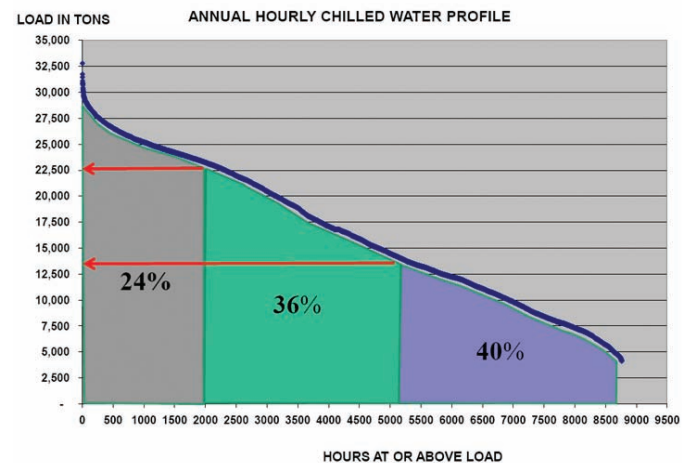


Figure 5: Campus load profile for the University of Austin at Texas

- Set up the automatic operation of the station in a way that guarantees equipment operational constraints are not exceeded
- There would be no hunting or instability to chilled or condenser water temperature, flow, or pressure.
- Cooling tower water and chemical usage would be reduced, because the cooling tower could be operated at intermediate speeds other than just high and low speed.
- Part-load efficiencies and varying condenser water temperatures could be capitalized upon.
- Chilling station efficiencies could be optimized for all load conditions.

Three modes of operation were designed into the controls strategy to address periods in which OptimumLOOP may not be working. This is described in Figure 6.

This planning led to a very successful project. The York Titan 5,000-ton chillers employed in this project are very efficient at peak kilowatt-per-ton efficiencies of around 0.60 kW per ton, with 85°F entering condenser water temperature. The campus was familiar with this equipment, as it owned two other York 5,000-ton chillers. The main difference is that the new chillers do not have gearboxes, and chiller loading is controlled via 4,160-V, 4,000-HP variable speed drives.

Prior to commissioning OptimumLOOP, the plant was operated

Control Strategy

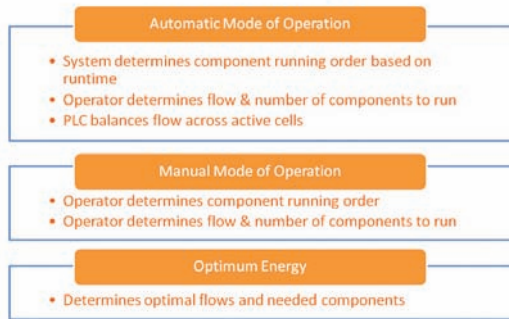


Figure 6: University of Austin at Texas Chilling Station 6 control strategy

without optimization for approximately six months to establish a before baseline. During this time, plant operation was tracked using OptimumMVM, the Web-based measurement, verification, and management service that is an integral component of the OptimumHVAC energy reduction system. The before baseline process established a total plant efficiency of 0.785 kW per ton, at 85°F, and the chiller was between 0.57 and 0.59 kW per ton, which met the requirement of the design-build contract.

With the OptimumLOOP optimization software in place, the Chilling Station 6 plant performance significantly improved.

- In November 2009, the plant achieved 0.423 kW per ton with a load of 4,918 tons, an entering condenser water temperature (ECWT) of 61°F, and with outside conditions of an Outside Air Temperature (OAT) of 53°F, Outside Air Humidity (OAH) of 61% RH, and a Wet Bulb Temperature (WB) of 46.5°F.
- Then, in January 2010, the total plant achieved 0.329 kW per

ton with a load of 4,705 tons, OAT of 32°F, OAH of 51% RH, and WB of 30°F. This was totally unexpected and was a very pleasant surprise. It has become apparent that we do not have personnel (engineer or otherwise) that would always be able to make the correct set point decisions to take advantage of all changing conditions on a 24-hour, 365-day-per-year basis.

While we do not expect to see these kinds of efficiencies in the peak summer cooling season, it is possible we see improvement when temperatures are cooler at night. We hope to average approximately 0.50 kW per ton the entire year, which translates to \$400,000–\$500,000 savings for the year. Expected savings for the plant over the existing older plant was only about \$140,000, plus \$840,000 for the inlet air cooler. This was much better than anticipated. Figure 7 is a screenshot of the OptimumMVM dashboard on January 7, 2010. The blue line is actual performance, and the red is prior performance. On this day, the real-time savings was 63%.



Figure 8: University of Texas at Austin's paradigm shift in the principles for district energy system management

The OptimumMVM Dashboard view shows real-time plant energy reductions, daily and monthly dollars saved, and carbon dioxide reduction levels, and is one of many views available to measure, verify, and analyze plant and equipment performance.

In summary, it has become apparent to the University of Austin at Texas's utilities organization that the paradigm of: "If you cannot measure it, you cannot manage it efficiently," has changed to: "If you cannot measure it *and model it*, you cannot manage it efficiently." We have learned that it is much less expensive to model processes, than to measure everything. A problem also develops when you gather a lot of data. It is difficult to see the right data and see its effect on the total system. We have applied this principle to our total plant, our chilled water distribution system, and now, our newest chilling station. We have used this knowledge to change the utility plant mindset, as illustrated in Figure 8.

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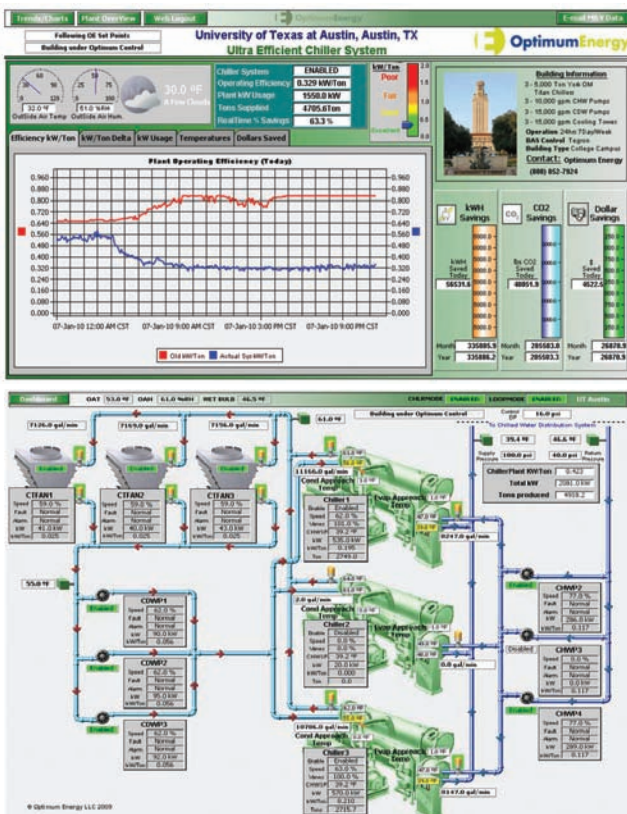


Figure 7: The OptimumMVM dashboard of the University of Texas at Austin Chilling Station 6 on January 7, 2010 shows a plant operating efficiency of 0.329 kW per ton.

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