The Missouri University of Science and Technology Campus Geothermal Energy System was a $33 million project that created three new geothermal plants to serve the heating and cooling needs of 16 buildings on campus, totaling over 1,000,000 square feet. These buildings include classrooms, laboratories, and offices. Additional spaces served by the geothermal cooling system, but not the heating water, include dormitories/apartments, a student center, and other classrooms and laboratories.

The system includes 645 vertical bore wells, each 420 to 440 feet deep, combined into closed loops serving the three plants. Each plant contains 500 tons of Heat Recovery Chillers (HRCs), cooling towers for heat rejection, and natural gas-fired boilers for supplemental heating.

The new chilled water distribution system from the plants was integrated with the existing 7 electric chiller plants for an automatically sequenced campus-wide 2-pipe chilled water system. The heating water distribution system from the plants is also 2-pipe and consists of two shared heating plants and one standalone heating plant. A life cycle cost analysis helped decide the hybrid geothermal plant design, incorporating HRCs with electric chillers and gas-fired boilers.

The existing campus buildings were modified to work with the new system. Coils were retrofitted for 120°F heating water. Also, the building chilled and heating water distribution systems were de-coupled from the campus mains for a primary/secondary/tertiary pumping configuration.

Energy Efficiency

An hourly energy model of the campus helped evaluate the energy efficiency of the geothermal system. Building heating and cooling loads were modeled with a DOE2 and Energy Plus based software. The geothermal system was chosen for its projected 50% energy savings over the previous systems in place.

The geothermal system uses the Earth as a battery to store rejected heat during the warmer months and extract it during the cooler months as a ground source heat pump. Additionally, the HRCs perform simultaneous heating and cooling for loads such as summer reheat, which helps accommodate the variable cooling and heating needs across the campus. At each building, modulating control valves regulate the chilled and heating water return temperatures to optimize the efficiency of the HRCs at the plants.

Indoor Air Quality

Previously, the single-pipe chilled water loop temperature often reached 50 degrees or higher, making dehumidification difficult. The campus can now achieve tighter control of the chilled water supply temperature with the added cooling capacity of the new HRCs, the new 2-pipe campus mains (separate supply and return), and integrated controls for chiller sequencing. Forty-five degree chilled water supply to each building enables proper dehumidification and increases occupant comfort during the warmer months.

At the end of construction, test and balance of the hydronic systems ensured proper flows to new and some existing coils in the affected buildings. It also helped improve the thermal comfort of spaces that had strayed from their original design flows. Since the airflows were not changed in this project, ASHRAE 62.1 was not addressed.

Innovation

The geothermal campus system was designed to optimize the first cost and energy savings, as well as create redundancy and reliability. The existing electric chillers supplement the HRC cooling capacity, while the new gas-fired boilers supplement the HRC heating capacity. Also, the hybrid systems ensure that the well field ground temperatures can be maintained within a stable range. The existing electric chillers can provide supplemental cooling and/or the plant cooling towers can reject heat to keep ground temperatures from exceeding the ideal range. On the other hand, the gas boilers can provide supplemental heating if ground temperatures drop below the ideal range or when the HRCs cannot meet the peak heating demands of the campus. The Owner may also choose to run the gas boilers instead of the HRCs if local utility rates make it advantageous to do so.

Operation & Maintenance

This project eliminated the deferred maintenance of the 40 year old coal and wood chip fired steam boilers in the power plant. Additionally, a two-pipe chilled water system sized for future expansion replaced the 40 year old single pipe chilled water loop.

A direct digital control (DDC) system serves all three plants and the building heating and chilled water pumps. Large screen TVs in each plant display controls graphics for the campus to simplify management and trouble-shooting of the geothermal system. The design team, commissioning team, and controls contractor worked cohesively to sequence the new HRCs, new gas-fired boilers, and existing electric chillers. The equipment is now automated for energy efficiency and precise control of the chilled and heating water temperatures. Extensive trend data is collected to help identify failures and opportunities for improvement.

A year-long comprehensive commissioning effort verified the installation, functionality, and control sequences of the geothermal system. This was necessary to ensure the system performance and reduce problems for facilities personnel.

Cost Effectiveness

The geothermal system was designed with hybrid heating and cooling systems to minimize the first cost and maximize the efficiency. Drilling enough wells to handle the peak heating load was not feasible due to the high costs and limited available real estate. The large number of wells could not be justified with energy savings when many of those wells would only be necessary for a few hours of the year. Drilling enough wells to handle 55% of the peak heating load allows the HRCs to handle 90% of the campus heating and 75% of the campus cooling throughout the year. The remainder of the heating and cooling loads are handled by less expensive gas-fired boilers and existing electric chillers.

The geothermal system is anticipated to cut total energy use of the Education & General campus buildings in half and save $1.1 million per year in operational costs for a 27 year payback. The project also modernized campus infrastructure by eliminating over $26M of deferred maintenance. The system has been in operation since July 1, 2014. Utility bills have shown energy savings of approximately 58% compared to recent years.

Environmental Impact

Missouri S&T committed to make the campus climate neutral under the University Presidents' Climate Commitment. The carbon footprint of the campus is a critical measure of its energy usage. The buildings utilizing the steam plant and single-pipe chilled water loop have a carbon footprint of 99.6 million lbs of carbon dioxide each year. Implementing the geothermal campus system is anticipated to decrease this carbon footprint by up to 50%, bringing the University much closer to its goal of carbon neutrality. The system is also projected to save 10 million gallons of water each year.