Case Study

University of Missouri District Energy Microgrid – 68 MW

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Project Overview

The University of Missouri, located in Columbia, Missouri, began operation in 1839 as the first land-grant university west of the Mississippi River. It is the largest university in the State of Missouri with a student population of over 31,000 students from all 50 states and 120 countries. The university's power plant is operated as a district energy micro-grid providing the campus's 16 million square feet of building space with onsite energy generation including steam, electricity, chilled water for cooling, underground utilities, drinking water, campus building automation, and energy efficiency options. At the heart of the system is a Combined Heat and Power (CHP) system that includes both natural gas and steam turbine generator sets. In addition, over 34% of the university's energy use is renewable with a portfolio of biomass, wind, and solar.

Figure 1: University of Missouri Power Plant (Source: University of Missouri)

Background

The university has a long and proud history in on-site energy innovation dating back to 1882, when Thomas Edison gifted the university an electric dynamo (DC generator) and his newly invented incandescent lightbulbs, which allowed the university to be among the first to experiment with electrically lighting a portion of one of its campus buildings. The university was also among the first universities in the U.S. to electrify

Project At-A-Glance

- SITE

  Location: Columbia, Missouri

  Sector: Colleges & universities

  Facility Size: 16 million square feet

  Campus Size: >31,000 students

  Peak Electric Demand: 50 MW

- DISTRICT ENERGY MICROGRID

  Electric Generation Capacity: 68 MW onsite electric generation

  Electric Utility Import Capacity: 40 MW 69 kV transmission connection

  Steam Generation Capacity: 1.1 million lbs/hr steam (up to 900 psi)

  Chilled Water Generation Capacity: >33,000 tons chilled water

  Under-Ground Utilities: 110 miles

  Current Fuel Mix: 64% natural gas, 31% biomass, <5% coal & fuel pellets

- TECHNOLOGY SOLUTIONS

  Combined Heat and Power (CHP):

  2 x 13 MW combustion turbines

  42 MW of 3 condensing, 1 non-condensing steam turbines

  300 kW backpressure steam turbine

  Wind: 20 kW wind turbine

  Solar PV: 34 kW PV array

  Solar Thermal: evacuated tube

  Boilers: 1 natural gas, 3 coal, 1 gas/multi-solid fuel, 1 biomass, 2 heat recovery steam generators (HRSGs)

  Chillers: 36 chillers (steam and electric)

- IMPACT

  Emission Reduction: 76% CO_2 emissions reduction

  Cost Savings: Cost of fuel plus purchased electricity per gross square foot of building space is 20% less than in 2015

  Resilience: Onsite electric availability 99.99% exceeds NERC national grid average its campus with CHP, building its first central power plant in 1892, combining steam generation with reciprocating DC generators to provide the campus with both on-site electric and thermal energy.

In 1923, the university opened a new power plant which provided both steam and electricity for the entire campus. The power plant provided up to 500,000 lbs/hr steam and 900 kW of electric power utilizing four coal fired boilers and two steam turbine / generator sets. As the university grew over the next 101 years, so did the power plant, still located today at the original address. Today the power plant houses the district energy micro-grid that produces up to 1.1 million lbs/hr steam, 68 MW of on-site electric generation, and > 33,000 tons of chilled water for space cooling.

Rationale

The University of Missouri's power plant is managed and operated as a campus utility enterprise that supplies utility services.. Their history of innovative on-site energy investments are guided by their mission to provide the campus with **Reliable, Cost Effective, and Sustainable** utility services. Investments are motivated in part by the fact that the campus facilities include not only academic and administrative buildings, but also highly critical hospital and research facilities which emphasizes the requirement to operate and maintain the district energy micro-grid system at an N-1 operational availability practice. This means the power plant has the ability to continue to meet campus peak energy requirements even if the largest single on-site generation asset (steam or electricity) is inoperative.

The investment decisions are also driven by cost effectiveness. Since the 1980s, the university has employed the use of Utility Master Planning as the mechanism that identifies and evaluates cost effective energy investments. It was the utility master planning process that resulted in the campus wide push for energy efficiency starting in the 1990s, on campus building energy performance and automation, and the continued upgrade of the on-site generation assets.

Finally, the university's commitment to energy sustainability is also driving their energy investments. The university is combining energy efficiency and renewable energy generation investments to reach their goal of consuming only as much energy (steam, chilled water and electricity) as can be produced on campus.

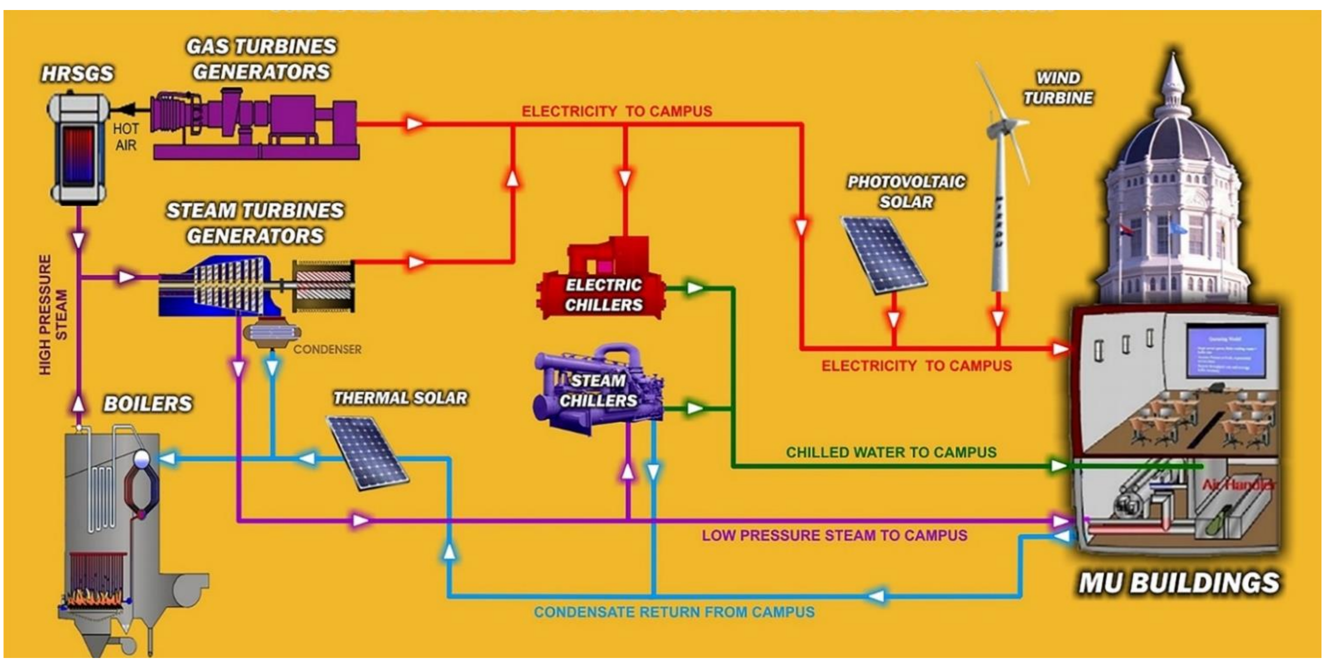

Figure 2: University of Missouri Power Plant District Energy CHP Microgrid Schematic Diagram (Source: University of Missouri)

Approach and Implementation

The university power plant that is in existence today has evolved over the past 101 years. It operates 24/7 with a wide range of equipment, some of which was installed as recently as 2002 (CHP gas turbine generators with heat recovery steam boilers), 2013 (biomass fueled fluidized bed steam boiler matched with a 19 MW steam turbine generator), 2017 (backpressure steam turbine generator), 2024 (8MW backpressure steam turbine generator) and some, such as steam turbine generators and steam boilers, dating back to the mid to late 1900s. Figure 2 is a schematic diagram that highlights the equipment configuration and process flow of the power plant.

Steam is the most critical and prevalent form of energy utilized on campus. It is produced by a series of six boilers as well as two heat recovery steam generators (HRSGs). The HRSGs operate by capturing the exhaust heat from two 13 MW CHP gas turbine generators. The current fuel mix to operate the steam system is comprised of 64% natural gas, 31% biomass. The remaining less than 5% comes from renewable paper pellets or coal. The steam system can generate up to 1.1 million lbs/hr of high pressure steam that is first utilized to generate electricity and then distributed throughout the campus at a lower pressure (60 psi) through 27 pipe miles of underground steam and condensate return pipes. The campus steam is utilized for heating buildings, sterilization at the hospital and research facilities, cleaning, production of chilled water, and other thermal energy needs.

Electricity: Utility grade electricity is produced through the use of two 13 MW CHP natural gas fueled turbine generator sets, four steam driven turbine generator sets totaling 42 MW, a 300 kW backpressure steam turbine providing parasitic power, a 34 kW solar PV array, and a 20 kW wind turbine. The total capacity of the on-site electric generation is slightly over 68 MW. In addition to the on-site generation capacity, the power plant has access to a 40 MW 69 KV transmission connection through the Mid-Continent Independent System Operator (MISO). The on-site generation provides, on an annual basis, approximately 83% of the electricity consumed by the campus. The remaining 17% of the campus electricity is economically purchased from the open access market, MISO. 89% of the open access market purchase is offset by a renewable power purchase agreement (PPA) with a wind asset in northern Iowa, in the MISO territory.

The CHP driven micro-grid normally operates in parallel with the electric grid, but is able to operate isolated from the grid if needed (islanded mode), has black start capability, is fuel flexible (natural gas and biomass), employs weather resistant underground distribution lines, has built in resiliency with multiple generation assets, and utilizes the electric grid as back up if needed.

Chilled Water: About 20 years ago, the university independently cooled the campus buildings with individual chillers located at each building. To improve the efficiency, reliability and cost of cooling the campus, the university, over time, developed a district cooling system that includes both steam and electric driven chillers located at the power plant and looped with various satellite chillers strategically located throughout the campus. The 36 chillers provide more than 33,000 tons of chilled water cooling, distributed through roughly 24 pipe miles of chilled water piping. The chillers are controlled and metered centrally by a process control system that maximizes chiller operation.

Renewable Energy: In 2013, the university added a biomass fueled fluidized bed boiler capable of producing up to 150,000 lbs/hr of 900 psi steam. The renewable fuel flexible boiler is matched with a 19 MW steam turbine generator set to produce electricity for the campus. Low pressure steam (60 psi) is extracted from the steam turbine after the electric generation, for use on campus. The boiler utilizes more than 120,000 tons annually of biomass, mostly wood residues purchased from Missouri sawmills and wood product companies.

In addition to the biomass unit, the university's power plant also demonstrates the use of renewable energy on campus with a 20 kW wind turbine generator and a 34 kW photovoltaic (PV) solar array, both producing electricity as part of the district energy micro-grid. A solar thermal heating system, which uses evacuated tube technology to collect thermal energy from the sun, is used to heat make up water for the plant's steam boilers.

Figure 3: CHP Unit 8 (Source: University of Missouri)

Results

The university power plant, which operates its district energy micro-grid and district cooling system 24/7 to provide the campus with reliable, cost effective, and sustainable utility services has accomplished the following results:

- Reliability of service has been extremely high, with the average annual availability factor for delivery of each of the utilities (steam, electricity, chilled water and drinking water) over the past 6 fiscal years at over 99.99%.
- The electric availability factor of 99.998% over the last five years exceeds the North American Electric Reliability Corp (NERC) reported national grid average of 99.92%.
- The cost of fuel to operate the power plant plus the cost of purchased electricity per gross foot of building space on campus is 20% less than it was in 2015.
- Energy usage per gross square foot of building space was reduced by 19% since the commitment to energy efficiency improvements on campus in 1990, with approximately $10.8 M annual utility cost avoidance and cumulative utility savings of $134M through 2023.
- >34% of the university's energy use comes from renewable sources (biomass, wind, solar).
- The efficient operation of the university's CHP based micro-grid and its commitment to renewable fuels has resulted in greenhouse gas reductions of over 76% since the base year of 2008.

Community Benefits

- **Local Economy:** Prior to 2013 and the installation of the biomass CHP system, the university was spending money on coal purchased from Illinois and natural gas from Oklahoma and Texas. Now, the university has replaced much of that expenditure with over $4 million annually spent on biomass wood residues from Missouri based companies, benefiting the local economy.
- **Reliability:** The University's district energy micro-grid serves the local community by both ensuring utility services to the on-campus hospital which serves the local community and by ensuring the university's facilities (e.g. food, shelter, and medical) are available to local residents during weather related emergencies, should the local electric grid be inoperative.
- **Living Energy Laboratory:** The university offers tours of its power plant facilities and its biomass, solar, wind and natural gas technologies to students and local residents, educating the local community on the advantages of energy efficiency and onsite energy generation technologies.
- **Environmental Benefits:** The university has reduced GHG emissions by 76% since the base year, 2008. These emission reductions not only benefit the students, faculty, and daily visitors to the campus, but also the local communities surrounding the university.

> *"A hundred years ago the primary fuel source was coal. The department started a transition away from coal in 2008. The current plant serves the campus needs with 34% renewable energy, the remainder primary fuel source is natural gas."*
>
> *- Michael O'Connor, Director of MU Energy Management*

Lessons Learned

- Achieving long term energy sustainability goals requires a clear vision, strategic and financial planning, patience and persistence, and most importantly a strong commitment by the whole university.
- Reaching a carbon neutral campus will become incrementally more difficult for large thermal users like universities, that must burn fuel to generate steam. Perhaps hydrogen fuel or more biomass are possible solutions.
- The present 68 MW micro-grid has only one tie-in circuit to the MISO grid, with only one transformer. Also, the available 40 MW grid capacity from MISO is insufficient to meet summer peaking loads, should the CHP become inoperative. These are potential electric reliability issues which are being addressed. The University is working on adding a second 40 MW electrical tie-in circuit to the MISO grid.

Contact Information

The 10 U.S. Department of Energy Onsite Energy Technical Assistance Partnerships (TAPs) help industrial facilities and other large energy users integrate the latest onsite energy technologies. For more information on this project and/or the services of the Onsite Energy TAPs, use the QR code or contact us at OnsiteEnergy@ee.doe.gov.

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