Case Study:
University of California San Diego Microgrid

The University of California at San Diego (UCSD) has a long history of self-reliance when it comes to energy. Opened in 1960, the university came of age in an era of energy awareness, and its founders sought to position the campus as a home for leading-edge science and technology research. Today, by embracing clean energy technologies in its operations and by collecting data to build an ambitious long-term sustainability plan, UCSD offers a glimpse into the future.

While academics and research are at the core of UCSD's energy initiatives, the university has also worked to integrate advanced energy technology into its campus. An on-site cogeneration plant, completed in the 1990s, produces more than 87% of electricity consumed. But beginning in 2006, the campus challenged itself to go further and develop a state-of-the-art, energy-independent **microgrid**.

Today, the campus produces 92% of its own energy. It's striving to go further with a combination of new clean energy resources, additional on-site generation and storage, and innovative demand-reduction strategies. The cornerstone of this effort is the OSIsoft PI System, which gathers data from hundreds of sensors, serves as a universal translator that synchronizes and coordinates operations of the campus' complex energy assets, and supports UCSD's efforts to create a sustainable environment for learning and innovation.

A 'Small City'

UCSD is a small city with diverse energy assets. The 1,200-acre campus is home to about 725 buildings comprising 13 million square feet of floor space. Forty-five thousand students, faculty, staff, and visitors churn through the campus daily. As a research and medical institution, it's two times as energy dense as a commercial park, consuming more than 250,000 megawatt-hours (MWh) of energy annually. The local utility, San Diego Gas & Electric, provides just 8% of the campus' annual energy needs. The remainder is generated from a diverse mix of on-site energy sources. OSIsoft's PI System helps the campus operations team keep track of and optimize various components:

- A 30-megawatt (MW) cogeneration power plant that saves $8 million in grid-energy purchases each year.
- A 2.8 MW natural gas-powered fuel cell [see sidebar below]. It provides electricity to the campus and usable heat to the cogen plant, increasing overall efficiency of the power plant and generating additional cost savings.
- Solar, in the form of 1.2 MW of traditional and concentrated photovoltaic panels located on site.
- 25 campus buildings, which use software from Johnson Controls to connect all their building systems and electrical meters to the PI System.

And that's only the beginning of what will be integrated into the growing campus microgrid in the years ahead. By synchronizing data from all these assets, the PI System helps UCSD efficiently maximize the use of least-cost, least-carbon resources to meet remaining demand.

Fuel Cell First

A 2.8-megawatt full cell provides about 8 percent of UCSD's total energy needs. The tennis court-sized fuel cell is one of three units throughout the San Diego region that utilize fuel from a directed biogas project at the Point Loma Wastewater Treatment Plant. It's the largest such system on any U.S. campus.

Before completing the directed biogas project, Point Loma flared more than 1.3 million cubic feet per day of digester gas — which is 60% methane — into the atmosphere. That made it an ideal target for climate-mitigation activities, because methane is more than 20 times more effective at trapping heat in the atmosphere than carbon dioxide. The project purifies biogas produced at the plant and feeds it into the natural gas pipeline; UCSD gets natural gas from the pipeline to power its fuel cell.

Encinitas, Calif.-based Biofuels Energy LLC owns and operates the system; UCSD buys the electricity produced by the fuel cell under a 10-year power purchase agreement. The fuel cell boosted the share of UCSD's electricity produced on site to 92%, up from 88%. In addition, the university plans to pair the fuel-cell with on-site storage to help it reduce the cost of grid-purchased energy. It does this with the help of the PI System-powered microgrid.

"The university's increasingly sophisticated microgrid will integrate all the campus' production, consumption and stored power and cooling water into one of the most sophisticated energy-management systems anywhere," said John Dilliott, energy and utilities manager for the campus, in a project announcement. "We will soon be able to factor in the variable cost of imported electricity and optimize the production and consumption of electricity in our entire system with a high degree of cost and energy efficiency."

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Solar Power

Solar makes up the bulk of UCSD's alternative energy generation. The campus operates a variety of solar installations on campus, including 1.2 MW of traditional photovoltaic panels, 30 kilowatts (kW) of SoiTech concentrating solar, and a Sanyo 30 kW "smart" solar installation with integrated storage, the first such system in the United States.

Currently, two of the rooftop solar arrays are outfitted with data connections that feed information from their electrical meters to the PI System. That allows the university to keep tabs on how much power the panels are producing at all times. Up next are the SoiTech and Sanyo systems; connecting these arrays to the PI System will also help UCSD take advantage of sophisticated tools that derive more value from the solar investment.

The PI System will eventually help manage the Sanyo smart solar array. Because the solar panels are paired with integrated storage, energy produced from the panels doesn't need to be provided to the grid immediately; it can be stored and used when market prices for grid energy are higher, or fed back into the grid during a surplus as a source of revenue.

"The main way of using storage-integrated systems today is to just install your panels and let them produce whatever the cloud cover allows you to produce," says Byron Washom, Director of Strategic Energy Initiatives at UCSD. But with solar forecasting data, market pricing data, and the ability to view these together through the PI System, UCSD will soon be making much more sophisticated, efficient use of its resources. "You're taking the intermittency and variability out of solar energy," he says.

Electric Vehicles

Another potential source of energy storage for solar and other renewables is emerging on the campus: electric vehicles. The on-campus fleet of electric vehicles is small today, but UCSD has emerged as a pioneer in green fleet management.

The annual Government Green Fleet Awards have ranked UCSD in the top 25 public fleets for the last two years running. The fleet comprises more than 800 campus vehicles,

including more than 50 hybrid-electric cars, five fully electric vehicles, and three charging stations. UCSD earned the UC/CSU Best Practices award for its electric-vehicle program, and it has been recognized by the California office of the Environmental Protection Agency as a "Model Pollution Prevention Vehicle Service and Repair Facility." Jim Ruby, the campus fleet manager, was recognized as a "Sustainability All Star" by *Green Fleet* magazine in October 2011.

One part of the campus fleet vision is using the PI System to enable a smart-charging infrastructure in the microgrid. With the expanding pool of solar on parking structures around campus, zero tailpipe-emission cars are an increasingly interesting possibility. To make it work, "you've got to understand the data," says David Zeglinski, Program Manager at OSIsoft. "In the concept, there's demand and generation, and you've got a battery pack in the middle to reduce power losses and allow direct vehicle charging from the solar plants. Integrating the electric vehicles to multiple solar plants and battery systems requires a real-time data infrastructure to coordinate all of the fixed and moving parts."

Today, it's not possible to connect solar panels directly to the vehicles for charging, but with increased data and energy management provided by OSIsoft and other partners, it's a likely part of the future. The PI System will also help UCSD go beyond simple vehicle charging. As the fleet grows, the issues around managing vehicle charging will also grow. As with the smart solar array, the PI System will integrate with solar data, vehicle battery status information, grid-energy pricing data, and more, to support modeling, charging and pricing systems.

Digital Infrastructure

The campus operational team encountered challenges in integrating its diverse energy assets while planning for the microgrid. Using the PI System has helped UCSD overcome these challenges by enabling it to take proven technologies and orchestrate them in innovative ways. The end result? Real-time information integrated across the campus, increased sustainability, and optimized renewable resources.

The OSIsoft PI System gathers data from many of the energy assets on campus, including both supply and demand sources. Sensors and systems around campus report, in real-time, everything from the energy being produced by the system's solar panels to the energy being consumed by devices plugged into the sockets of some buildings. Today, just 25 buildings on campus — less than 4 percent — are connected to the PI System, but that's still enough to produce 76,000 data streams. Ultimately, UCSD hopes to connect all occupied building space on campus to the PI System; that will scale with the number of data streams — called tags — to more than 1 million, revealing continued insights for improvements and breakthroughs.

Capturing this abundance of data, in real-time, is a fundamental building block for any microgrid or robust energy-management project. It's also one of the biggest challenges engineers face with energy management. Many of the data sources spit out data at 1-second and 1-minute intervals; others go well beyond that, reporting sub-second information. Many data collection systems can't handle that volume of data so they end up averaging data over longer intervals and deleting the original source data. This can mask potential problems and, therefore, potential areas for optimization. The PI System avoids this by using a fast-camera approach. Data are rapidly fed into the system, archived efficiently, and can be easily retrieved for analysis.

Another challenge energy managers face is the diversity of data protocols and output formats involved in complex energy systems. "Many of the data protocols we see on campus from our vendors were intentionally developed as proprietary — that is, non-interoperable — formats," says Washom. "Imagine if you were at a UN meeting, and all the translators were on strike. Everybody at the meeting would just stand there and look at each other. Nothing would happen. That was our situation. So, for us, OSIsoft is this Rosetta stone. They now allow us to communicate in a common language throughout the campus."

The PI Server provides this translation function using hundreds of custom-built **PI Interfaces**. Two such custom interfaces are currently pulling data at UCSD [see sidebar below]. "To the OSIsoft folks, that's peanuts," says Washom. In other customer implementations, the PI System integrates hundreds of different data protocols and systems; but this flexibility is what makes the PI System ideal for UCSD. While it's supporting a small microgrid project today, it can be used to gather data on much more, adapting to constantly evolving situations, and offering relational and global

A Rosetta Stone

PI Interfaces are what allow the PI System to integrate diverse data sources, regardless of their protocol, standard, or language. OSIsoft's team has developed a library of hundreds of these translators, and on the UCSD campus, its leveraging two of its existing Interfaces as well as developing a third, new PI Interface to address specific issues on the campus network.

OPC: An industrial automation standard, OPC is one of the most widely used protocols in the power industry. OSIsoft is a founding member of the OPC foundation, which manages the standard and certifies products as compatible with it. There are millions of devices and systems using OPC, worldwide, including the UCSD campus. Today, the central utilities plant and solar panels are connected to the PI System using the the PI Interface for OPC DA.

BACnet: A widely used standard for building automation systems, BACnet (Building Automation Control Network) is a critical piece of the Johnson Controls systems that are in use on the UCSD campus. The PI Interface for BACnet translates data produced from these systems — which report building energy use in real-time — into the PI System for integration with other data sets.

Schneider 7000 and 3000 series meters: Power producing assets on campus are connected to meters, which flow data on power production to the interfaces. The fuel cell and rooftop PV panels are connected to meters manufactured by Schneider Electric, which report data using a propriety protocol. Through a licensing agreement, OSIsoft is creating a new PI Interface to translate this data into the PI System directly. This will allow the PI System to communicate more directly with the devices, providing more accurate real-time data for campus energy managers.

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perspectives as the project and the university's needs evolve. As UCSD continues to expand its generating assets and upgrade the systems in its facilities, OSIsoft will continue to add data streams to the PI System. It takes less than a day to integrate new assets into the system, says Zeglinski. "We had the data from the new fuel cell into the PI System and one display screen built in a couple hours," he points out. The only limits are on what UCSD chooses to add into its system.

Compatibility

Managing the microgrid requires OSIsoft to work in harmony with two other critical software platforms. The PI System, which runs on an on-site Windows Server, translates, presents and provides visibility into this data via dashboards for human users. It also feeds this data into a system from Power Analytics, which responds to information provided by the PI System to ensure high degrees of reliability and efficiency across the entire microgrid.

"Power Analytics knows how our system should be performing — what we call 'perfect on paper.' Every time it sees a divergence, it can analyze it and recommend what needs to get changed, make those changes, and monitor in real-time to see if the changes are effective," Washom explains.

OSIsoft also interfaces with Viridity, a software platform that looks at dynamic market pricing signals and re-optimizes, on an hourly basis, where UCSD should be sourcing its power from, how it should be storing energy on-site, and when it should be feeding energy back to the grid.

Together, OSIsoft and its technology partners help users find information they need to make the most informed, efficient decisions to improve performance of the UCSD system.

"OSIsoft is constantly pushing the envelope and going to higher and higher levels of innovation. They're taking us to a new level that we wouldn't even be approaching without them."

— Byron Washom, UCSD

Living Laboratory

The PI Server lowers the cost of curiosity by providing users access to high-speed, high-fidelity data in the appropriate context. For a university, this is a valuable asset. With a data infrastructure in place enterprise-wide, the PI System creates data literacy across the campus and helps support an organizational culture built around openness, collaboration, and sustainable innovation. Now, UCSD is looking to push that openness even further.

By leveraging **PI Coresight**, UCSD is working to put all the data about the microgrid's operations online, allowing any public web user to access the system's performance information and help improve its operation. PI Coresight offers opportunities to collaborate and look at data from different angles to create solutions and opportunities.

Anyone can access PI Coresight from locations around the world, and it can be presented in a variety of ways. In democratizing the data, there are new opportunities to perform research with other universities, expose projects to students, crowdsource ideas, and share best practices.

The potential for this kind of radical transparency is huge. "The more eyes and brains focused on this data, the more innovation we will experience," Washom says. "If I get 1,000 people looking at our microgrid, that's a tremendous increase in the resources I have available to me."

As a public research institution, UCSD hopes to see its initiative inspire innovation cross the country and around the world. To this end, the university is also working to integrate its PI System implementation with those in place at the utilities and grid operators supporting UCSD's microgrid.

OSIsoft's long-time experience in the utility space means that more than 65% of the electrons produced across the United States are delivered by utilities who use the PI System for operations monitoring. But in most cases, these grid operators can't see what happens once power is delivered to end users. Washom wants to change that and help spur further knowledge about how microgrids can play a valuable role in making energy systems more sustainable, reliable and efficient.

"They can't see behind the meter to see all the gymnastics we're going through to optimize our energy use or supply demand response," he explains. "Until they know more about what goes on behind the meter, they won't be comfortable using us to the best possible advantage in the overall grid."

By leveraging the **PI to PI Interface**, UCSD can give power providers visibility into everything its own plant operators can see. "They will gain confidence in us and become more of an advocate for microgrid development," Washom says.

Future Forward

While UCSD's microgrid is small, the impacts of the project are large, positioning the university well ahead of its peers.

Certainly, there's the financial aspect; according to Washom, the OSIsoft project stands to amplify the savings impact of the university's central plant, which currently amounts to $850,000 per month. But that's not the only benefit. UCSD's microgrid is also helping establish the future of clean energy technology and leadership, as well as building awareness of and confidence in the potential for microgrids worldwide.

By showcasing renewable energy technologies, sensors, software, and more, the microgrid project has differentiated UCSD as an energy innovator and furthered its reputation as a leader among higher education institutions. By exposing students, faculty, and researchers to the technologies, methods, and challenges associated with this innovative system, the university is helping train the next generation of

energy leadership. With hands-on experience and insights, these individuals will play an important role in creating technologies and companies for tomorrow.

UCSD also believes its experience will demonstrate the opportunities for microgrids to create secure, reliable clean energy infrastructure in sustainable communities everywhere. "Our goal is to increase the viability and utility of microgrids being managed in the system," Washom says.

The PI System provides the kind of scalable, easy-to-use technology required to drive innovation ahead, while also offering transparency and accessibility to support UCSD's public outreach efforts. As more technologies are tested on the campus microgrid, UCSD uses data collection as its foundation for building a long-term, leading-edge sustainability plan that offers a pathway to the future.

PI Coresight for Community

Opening up the data from the microgrid is one of the most exciting projects on the table for UCSD. With a small team working on the project internally, the ability to publish their data sets online is an opportunity to expand the circle of expertise about how to improve and innovate on the microgrid. Collaboration and transparency will support the university's educational mission, while helping eek additional efficiency out of the system and uncovering new opportunities for innovation.

The PI System offers several ways of making this data accessible to managers, partners and the public. UCSD is leveraging PI Coresight, the latest addition to the PI System's repertoire of tools. It allows users — even those who aren't familiar with the PI System — to access the data they need to answer their own specific questions.

PI Coresight, a web-based product that runs on Microsoft Silverlight, allows users to search a database of all available information sources and select any combination of assets, data streams (tags), or even other users' displays to be combined on a personalized display. Users drag and drop data they want to use, and Coresight manages the rest. In under an hour, new users can be up and running with a new display that shares the resources, dimensions and metrics they need to inform their decision making — or just their curiosity.

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