WHITEPAPER

How data conquers challenges of campus facility operations management

Executive summary:

With condition-based maintenance, fault detection, and diagnostics, campus facility managers use data and analytics to help universities save money and provide better services.

Introduction

A university campus is like a body. Buildings are connected by circulatory systems of air and water. Heat and energy come from central plants. Fuel keeps all of the systems running.

When problems arise with complex systems, taking a holistic approach is the best way to keep operations efficient, drive real cost savings, and identify the root causes of issues. This is especially true of universities because of their physical complexity. With hundreds of buildings of different ages and structures spread out across the campus, or even multiple campuses, a typical university poses operational and maintenance challenges greater than most commercial facilities.

The path toward holistic management is through intelligent data management: collecting real-time information across a wide variety of assets and organizing it all in a central location so it can be easily visualized and put to use. By making better use of data, universities can predict problems with buildings and systems before they occur, identify which maintenance tasks shouldbe the highest priority, save money and energy, and improve the quality of service to building occupants.

This paper covers two important types of asset management operations use cases that can protect building systems: condition-based maintenance (CBM), fault detection and diagnostics (FDD).

CBM is used with large critical assets like central utility plants to predict and prevent operations issues that could increase operations costs or even cause systems failure.

FDD is used with HVAC systems and equipment to help engineers determine when building systems aren't performing optimally. It also helps engineers decide how and when to fix issues.

Used in combination, with a central infrastructure that can organize and analyze real-time asset data, these two approaches can guide a more integrated and proactive approach to campus physical plant management.

What operations data can do

Building systems have thousands of things that move – dampers, motors, valves, and fans – and when small things fail, the system self-adjusts, responding to the problem without knowing there is one.

If a filter is clogged, for example, the system creates more airflow in order to keep cooling a room to its target temperature. Increased airflow, then, is one data point that could reveal the hidden problem of a clogged filter.

Unless the underlying problem is addressed, the harder working system costs more than necessary to operate and is at risk of failing completely.

Individual assets such as boilers and chillers already have sophisticated control systems that use real-time operations data, but multiple pieces of equipment connected into a building system create additional points where the risk of failure and opportunity for improvement exist. Analyzing operations data from these assets enables facility professionals to proactively maintain systems rather than run them to failure or wait for a call from a dissatisfied occupant.

CBM for managing central plants

On large university campuses, corporate research facilities, airports, or hospitals, the facility professionals who monitor and maintain the central utility plant have a complex set of asset management challenges. Consider a typical central plant facility maintenance team that oversees the power and space conditioning for 200 buildings, serving tens of thousands of occupants: This group monitors a combined heat and power plant, as well as a substation, chiller plants, and a utility distribution network with miles of underground steam piping and dozens of underground feeder loops. The facility executive may have people dedicated to operations and maintenance or may outsource these functions.

Facility professionals face significant challenges

- A lack of situational awareness of what's happening in real time at their plant.
- No visibility into asset health, which means an inability to hold vendors accountable if asset maintenance has been outsourced.
- Hidden costs related to energy contracts or maintenance activities.
- Difficulty adapting to new technologies, such as renewable energy.

This paper will look at these challenges in greater detail to demonstrate how data, analytics, and condition-based maintenance (CBM) can meet them. But first, let's understand CBM.

Understanding CBM

Condition-based maintenance uses data from equipment sensors and plant control systems to determine when maintenance is best performed to:

- Reduce the risk of equipment failure and unplanned downtime.
- Increase asset health and overall equipment effectiveness.

Data for CBM can come from equipment that provides on-line monitoring of things like temperatures and start/stop sequences. Data may also come from offline eddy current, oil analysis, and other diagnostic tests, as well as from portable test equipment like infrared cameras.

CBM requires a shift in mindset for facility maintenance professionals. Previously, maintenance was performed on a fixed schedule, so assets would be maintained at regular intervals. However, assets don't degrade at a fixed rate, so this is not the optimum way to maintain them. Rather than rely on vendors or staff to make assumptions based on time and experience (e.g., "We know that after 500 hours of operation, the performance will probably have degraded 25 percent"), CBM lets staff use real-time data to perform maintenance when it makes the most business sense to do so.

Benefits of CBM

Implementing CBM extends maintenance cycles, thereby reducing maintenance costs. At the same time, as costs fall, asset reliability and availability actually rise. That's because calendar-based processes often generate unnecessary maintenance that takes equipment out of service more often than required. Or worse, a calendar-based approach may fail to catch a serious issue that arises before scheduled maintenance and cause equipment to fail. And just performing maintenance has the potential to cause problems with equipment.

Perhaps most important of all, CBM helps avoid the high price tag of unexpected failures and emergency repairs. Those costs can go well beyond the dollars paid for the work on the equipment itself, as expensive as that can be. Loss of critical power or HVAC systems often entails additional hard and soft costs when buildings cannot be used for their intended purposes.

Condition-based maintenance software can make use of real-time data and analytics to tackle critical challenges faced by facility professionals.

Finding hidden costs

When central plant managers have access to real-time operations data, know the costs of their energy contracts, and know the cost of failure, they can monetize that knowledge with CBM. Managers can optimally design maintenance programs based on actual conditions, such as real-time pricing for utilities; interruptible gas supply contract prices, penalties, and penalty triggers; demand charges for the region; power loads for the time period; etc. Analyzing these energy management data points can reveal cost reduction opportunities.

CBM data also can be used to find hidden problems in specific systems. The Central Plant at MIT makes chilled water, electricity, and steam that it distributes to approximately 120 campus buildings. After installing the PI System to get a better view of their operations, they discovered that the chilled water differential (the difference in temperature of water going to a building and water coming out) was virtually zero.

Further analysis of the meter data revealed a very costly problem: a control valve with no sensor on it was stuck open. Broken, the valve allowed chilled water to flow at an astronomical rate of 1,200 gallons per minute. Fixing the stuck valve changed the flow rate to 150 gallons per minute – and delivered estimated savings for a single year of $60,000 to $80,000.

Improving situational awareness

In 2015, when a massive power outage hit the University of Maryland, College Park, research campus, the university was forced to close for several hours as the central plant's facility management team sought to restore steam, power, and lights to buildings serving 49,000 students. At that time, there was only one place that workers could see what was happening at the power substation: the cogeneration plant control center.

With that lack of visibility, workers didn't know where the problems were, and it took more than five hours to restore power to the campus.

According to Don Hill, assistant director of facility management, that incident sent the university on a quest to find a more effective way to gather, visualize, and analyze critical facility data. The university ultimately installed the PI System and built its own CBM system on top of it. The PI System was able to pull in data from several legacy systems, data that was then visualized to show the power status of buildings and feeder loops so staff could monitor the operation of steam pump in real-time.

A clear view of asset health

Outsourcing the operation of central plant facilities can make sense; it allows an organization to reduce costs, tap expertise that the organization doesn't have in-house, and improve operations. But this performance contract method of asset management can mean the central plant building owner loses awareness of the condition of essential equipment. That puts the owner at the mercy of the vendor.

The vendor could decide that it's cheaper to not maintain an asset and still meet the deliverables in the contract. But if something goes wrong, it's the owner who could be subject to unexpected costs.

One facility in the Northeast outsourced the operation of its central utility plant under a performance contract model. The facility had an interruptible gas supply contract, so they paid a lower rate for gas because their service could be interrupted at the utility's discretion.

Typically, when gas service was interrupted, they switched to oil. Because the vendor had not performed good maintenance, they lost the ability to switch to oil. This happened when those assets were needed to fulfill their energy contracts. As a result, the facility had to pay a penalty of more than $1 million to the gas company for not being able to execute that interruptible gas supply contract.

As with any outsourced or performance contract, it is important to maintain situational awareness in order to monitor the vendor to ensure compliance with the contract as well as to protect the mission-critical infrastructure and assets of the facility.

Better ability to plan for changing technology

Campus central utility plants are facing changing demands that are difficult to plan for, with more renewable generation, less use of steam, and increasing demand across the board as a result of facility growth. What's more, regulatory and policy demands may force a strategic shift, requiring the organization to become zero-carbon, to increase resiliency, or to achieve certifications for energy efficiency.

These factors could change the nature of central plant operations. They bring an increased number of control systems and data sources as well as increased reliability demands because facilities must balance the availability of traditional assets – for power, steam, chilled water, and hot water – with new systems and new energy contracts.

CBM has a role in maintaining these systems, and the ever-increasing interdependencies and increased expectations of availability. If these systems go down unexpectedly, the failure could lead to financial penalties from loss of basic services.

The PI System provides data

The challenge with implementing CBM is ensuring that the system has the data it needs. That's no small task. Asset data may exist in a wide variety of systems and in a range of formats, from delta pressures to corrosion inspection results to thermography information. And the different types of equipment that provide the data generally don't talk to each other, leaving the information stranded in siloes.

The PI System provides an open infrastructure to automatically pull together data from a multitude of sources across the central plant or the campus. Gathering data automatically is both faster and more reliable than manual data gathering.

The PI System integrates, standardizes, and centralizes data to connect sensors, operations, and people across the enterprise. It organizes and converts raw data streams into meaningful events and values. It can deliver data to other advanced analytical tools and engines. And the PI System does all that in a highly efficient, highly secure manner.

Event Frames and Notifications are features of the PI System that capture, store, and enable the viewing of pertinent data in one place and in a consistent format. They enable users to quickly identify problems, discover the root causes of outages, or monitor systems to prevent problems. This turns asset data into useful and actionable information.

Event Frames automatically bookmarks process events. An "event" can be many things: the start-up of the HVAC system, a single room sensor detecting "occupancy," or an attempt to access a control panel. The Event Frame captures the start time, end time, and duration of the event, and as well as any other events or data happening simultaneously. The Notifications feature lets users configure "notification rules" to send email messages or to call a web service when a specific event happens. The user can configure message content and set up escalations, and all notification actions – such as notification send times, acknowledgments, entry of comments, and escalations – are stored for later retrieval and examination.

FDD for managing individual building systems

When it comes to individual building systems, most facility managers aren't used to looking at data. They address comfort complaints and respond to maintenance needs, but they seldom go back to understand why problems occurred. In most cases, they don't have time to trend and solve those issues.

Facility staff typically attend to systems from a control point of view: They check if the equipment is on or off, or if temperatures or voltages are correct. Historical data may be looked at monthly – or not at all. Facility managers don't know how their building systems are actually performing, which can mean missing costly problems.

Fault detection and diagnostic (FDD) software can use real-time data generated by building systems to identify root cause issues and help facility staff take action. Like CBM, FDD is a set of analytics performed on real-time data that enables facilities to identify and respond to problems and helps engineers determine where to put their time and attention.

Benefits of FDD

Quick problem identification and repair

FDD helps facility managers find problems and fix them. Real-time data, like supply temperature, outside temperature, or air flow rates, is combined with formulas and algorithms that indicate when something is wrong with a system – before a complaint call is received. FDD can also indicate why a problem occurred so technicians can fix the underlying issue.

On one campus, PI System data revealed that one building had simultaneous heating and cooling going on. Upon further investigation, technicians found a broken three-way valve that was allowing both hot and chilled water to flow into the pipes at the same time. They were able to correct that unreported problem and eliminate a potential risk to the whole system. And, because the working valve reduced the flow of water, the fix reduced operating costs by about 5 percent.

Prioritizing maintenance tasks

One benefit of FDD is maintenance prioritization: Minimizing cost, time, and effort without adding facilities people while still maintaining a comfortable environment. FDD identifies problems by applying rules to data from a control system. For example, the system might have a rule that sets minimum and maximum values for delta T in the chilled water loop. If the data doesn't conform to the rules, the system will identify a fault. One challenge with FDD is the very large number of potential faults it might find.

FDD solutions should put a dollar value on the cost of problems – for example, by tracking the amount of energy wasted as a result of a fault like a damper being stuck open – so that maintenance can be prioritized to address the costliest issues first.

Energy optimization

FDD systems can be used to optimize energy use in building systems. The University of California, Davis, for example, set out to reduce energy use through ongoing commissioning using FDD. Ongoing commissioning is a process that seeks to ensure that building systems continue to operate as they were intended; it often combines powerful software like FDD with human expertise to identify and correct problems that waste energy.

Having already improved performance through commissioning existing building systems and a review of building management system (BMS) controls, UC Davis chose two buildings in which to pilot FDD software, which is designed to preserve those savings and enable deeper analysis with continuous monitoring.

The types of optimization opportunities uncovered by FDD include temperature sensor failures; valves cycling on and off unnecessarily; smoke dampers stuck closed; and HVAC operation not matched to occupancy.

With those faults uncovered and corrected, the two pilot buildings have shown a 22% and 24% savings in energy use costs (savings include those from both the building-commissioning and FDD systems).

The Kellogg Company used the PI System to create consumption benchmarks prior to setting 10-year energy targets for a critical facility; Kellogg's also installed air and gas metering as well as voltage monitoring. So far, it has done 30 projects using data from the PI System. Since 2005, the facility is saving $3.3 million annually, and PI System data has helped it qualify for $1.8 million in rebates.

The PI System provides data for fault detection

Many building systems already collect data in some form, and FDD algorithms can identify a wide range of specific problems. The challenge for facility managers is to gather the data from disparate sources and feed it to the FDD system. A building may have many different systems that do not communicate with each other. For example, the lighting control system may not talk to the BMS, and the proprietary protocols in different BMS may not share data with one another. And new technologies like dynamic glass or automated blinds may not be able to communicate with the automation system. Even if equipment is communicating, getting the data into a form that will make it useful for FDD can be a challenge.

As with condition-based maintenance, the PI System can play an important role in fault detection and diagnostic efforts by integrating, standardizing, and centralizing data so that it can be used by the FDD system. The PI System can organize and convert raw data streams into meaningful events and values and also combine data from wide-ranging sources.

At UC Davis, even though 70% of the larger buildings on campus used the same BMS, the facility staff couldn't use sensor data to actively understand what was happening with equipment. Building automation/control systems often lack analytics to allow facility staff to easily identify problems from data, even data from within the BMS. So the energy team at UC Davis imported data from the BMS into the PI System.

UC Davis used the PI System to create and edit tags in bulk. It generated 11,000 tags for the two buildings in the pilot study. Staff used granular data supplied by the PI System to understand problems more quickly. With analytics in the PI System, UC Davis reduced wasted air flow, saving energy costs.

And the PI System templates developed for the pilot project can be applied to other buildings as UC Davis expands the program; the target is 70 buildings with 300,000 tags.

Conclusion

Condition-based maintenance and fault detection and diagnostics are increasingly being implemented to take advantage of real-time data from buildings to improve equipment performance, reduce costs, and keep building occupants satisfied. Pulling that data together and putting it into a form useful to CBM and FDD can be a daunting challenge.

The PI System can serve as a bridge between sensor data and powerful applications like CBM and FDD. It provides an efficient and secure means to standardize, integrate, and centralize data from disparate sources.