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Control of Computer Room Air Handlers Using Wireless Sensors

Energy Efficient Data Center Demonstration Project

State of California Energy Commission

State of California Franchise Tax Board

Department of General Services

EMERSON Network Power

FEDERSPIEL CONTROLS

BERKELEY LAB

vte CLEANROOM & DATA CENTER SPECIALISTS

Silicon Valley Leadership Group

About the Energy Efficient Data Center Demonstration Project

The project's goal is to identify key technology, policy and implementation experts and partners to engage in creating a series of demonstration projects that show emerging technologies and best available energy efficiency technologies and practices associated with operating, equipping and constructing data centers. The project aimed to identify-demonstrations for each of the three main categories that impact data center energy-utilization:

operation & capital efficiency

equipment (server, storage & networking equipment)

data center design & construction (power distribution & transformation, cooling-systems, configuration, and energy sources, etc.).

The project also identified member organizations that have retrofitted existing data centers and/or built new ones where some or all of these practices and technologies are being incorporated into their designs, construction and operations.

About The Silicon Valley Leadership Group (SVLG)

The SVLG comprises principal officers and senior managers of member companies who work with local, regional, state, and federal government officials to address major public policy issues affecting the economic health and quality of life in Silicon Valley. The Leadership Group's vision is to ensure the economic health and a high quality of life in Silicon Valley for its entire community by advocating for adequate affordable housing, comprehensive regional transportation, reliable energy, a quality K-12 and higher education system, a prepared workforce, a sustainable environment, affordable and available health care, and business and tax policies that keep California and Silicon Valley competitive.

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Dynamic Power Management: Adjusting Data Center Capacity in Real-Time

This project demonstrated how a wireless sensing network, provided by Federspiel Controls, can be used to directly control computer room air conditioning devices. Several air management improvement strategies were also implemented, e.g., air curtains, that worked together with the control system to achieve significant energy savings. Using the wireless sensors, fan speed and chilled water flow were adjusted to provide the optimal amount of cooling to the IT equipment. Changes were made incrementally to compare the effect of each measure on energy performance. Annual data center energy consumption was reduced by 475,239 kWh, which is over 21% of its original baseline energy use. This energy reduction results in eliminating more than 400 Tons of CO_2 greenhouse gas emissions per year. Total project cost amounted to $134,057 with an annual savings of $42,772 resulting in a payback period of 2 ¼ years, after including rebates. The demonstration was hosted at California's State Franchise Tax Board data center in Sacramento, CA.

Project Case:

The combined effect of overcooling, fighting instabilities, and non-uniform or variable loads in datacenters has generated a need for more accurate control of datacenter cooling. This case study demonstrates the use of wireless sensor networks for supervisory control combined with improved air-distribution best-practices in an enterprise datacenter. The datacenter is a 10,000 square foot (929 m^2) raised-floor room at the California Franchise Tax Board. The datacenter is cooled by twelve (12) 22-ton computer room air-handling (CRAH) units using chilled water for cooling. The CRAHs have reheat and infrared humidifiers, but these capabilities were disabled by the operations staff. The CRAH units deliver air to a raised-floor plenum. The datacenter had an overhead plenum, but it was not being used for return air to the CRAH units. The datacenter was originally built out to 40% of capacity with 77 racks, but a virtualization effort prior to the start of the project reduced the IT load delivered from the UPS to 143 kW.

A wireless mesh-network of 46 temperature sensors was installed at various positions to provide air temperature feedback at the IT equipment inlets. The mesh network feedback was used to determine which of the 12 CRAH cooling units to operate, and to reset the setpoints of the operating cooling units. Interfacing the wireless supervisory control system with the cooling unit controls was facilitated by the open communication protocol of the cooling and power units in the datacenter. Four CRAH cooling units were converted to variable-speed operation with variable frequency drive retrofits. In addition to correcting air distribution degradation, containment curtains were added that separated hot air from cold air in the aisles to allow the cooling units to draw heated return air from an overhead plenum. Energy and environmental control improvements of the control system were documented,

Measure	Cost	kWh/yr Saved	% Saved	$ Saved	Rebate	Payback
Re-arrange tiles	$3,000	44,496	2.0%	$4,005	$3,560	-0.14
VFDs	$16,040	75,135	3.4%	$6,762	$6,010	1.48
DASH Control System	$56,824	339,603	15.2%	$30,564	$27,168	0.97
Hot aisle containment	$58,193	16,005	0.7%	$1,440	$1,280	39.51
TOTAL	$134,057	475,239	21.3%	$42,772	$38,018	2.25

Table 1: ROI analysis. Note: DASH is a product of Federspiel Controls.

including the impact of variable-speed fan operation and separation of hot air from cold air using strip-type curtains. Energy and thermal performance was documented using a before-after measurement and verification approach that included component energy monitoring for a two-week period before and after installation.

ASHRAE and IT equipment manufacturers (servers, network equipment, and storage equipment) have collectively reached consensus on recommended environmental operating ranges for datacenter IT equipment air inlet conditions of 64.4-80.6 deg F and 42-59 deg F dew point (with a maximum 60% relative humidity). To operate datacenter IT equipment at the recommended temperature range, cooling units are often placed throughout datacenters. The cooling units also have on-board digital controls and embedded sensors that measure temperature and humidity of the air returning to the cooling unit. The digital controls in the cooling units operate to keep the return air temperature and humidity close to values set manually by an operator. Placing the temperature control in the return to the air handler in general creates a source of confusion for data center operators who often think this is a supply temperature. Since the cooling unit controls do not monitor the server inlet air temperature, data center operators do not have inlet air information. As a result and to mitigate hot spots there is a tendency to set the cooling unit's setpoint too low to ensure that the hottest server equipment is satisfied, thereby causing overcooling and, consequently, wasting energy. Overcooling may actually adversely affect IT equipment reliability. At the FTB, the baseline IT load was 143 kW measured at the center's uninterruptible power supply (UPS). The installed cooling capacity is 240 tons, which equates to 840 kW; therefore, 5.9-times more capacity than the measured IT load was available.

The Green Grid Metrics	Baseline	Post Install	4 months later
Total Data Center Power (kW)	259	200	191
IT Equipment Power (kW)	143	142	142
CRAH and Cooling (kW	111	53	44
Verified Post Installation Data Center Power		200	
Power Usage Effectiveness (PUE)	1.81	1.41	1.35
Data Center Infrastructure Efficiency (DCIE)	0.55	0.71	0.74

Table 2: PUE Calculation.

Although the cooling units in a datacenter may be networked for remote monitoring, they are normally controlled in a standalone, decentralized mode. This often causes "fighting" between cooling units. One unit may be trying to humidify, which causes another nearby unit to cool more, and in doing so condense moisture from the air, which causes the humidifying unit to work harder, and so on. As IT equipment density increases, cooling units are getting closer together, which results in more fighting. At the FTB, most of the time humidity control and reheat was turned off, so there was generally no contending between humidity control and temperature control. However, supply air temperature oscillations were recorded, due to interactions between CRAHs.

Project Outcome

This demonstration project exhibits how wireless sensors combined with control software along with air management measures can be used effectively to improve temperature distribution and reduce energy use in data centers. In addition to demonstrating how this technology can be used, specific "best practice" measures were implemented. These measures are readily implemented in most conventional data centers and can result in significant energy savings with relatively short return-on-investment (ROI). Although the goal of this demonstration was not to optimize all available opportunities (e.g. raising chilled water temperature), substantial energy

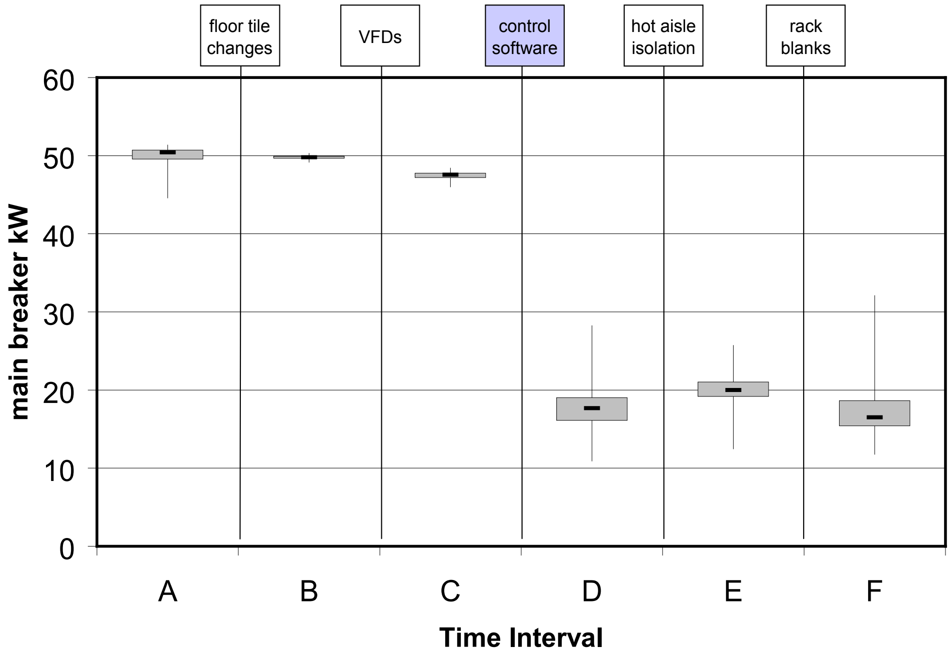

Fig. 1: CRAH electrical energy consumption before/after each measure.

savings were achieved. The overall project eliminates 475,239 kWh per year, which is 21.3% of the baseline energy consumption of the data center. The total project, including the best practices saves $42,772 per year and cost $134,057 for a simple payback of 3.1 years (without rebates).

Of the project's overall energy reduction of 21.3%, the control system alone eliminated 15.2 % by reducing the energy used to move air by 59.6% and the energy to cool the data center by 13.6%. All of this was achieved while keeping temperatures within the limits recommended by ASHRAE. The control system alone saved $30,564 per year and cost $56,824 for a simple payback of 1.9 years.

In summation, the control software had the biggest energy-reduction impact. Rearranging the floor tiles produced the largest reduction in chilled-water energy consumption (followed by the control software), but confounding factors such as heat exchange with the building air-handling system or manual control of the cooling units could have contributed to the observed changes in chilled water consumption. The datacenter's DCiE was increased from 0.55 to 071, which equates to a PUE was improvement from 1.81 to 1.41.

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