Getting the Most Out of Your Building: SMUD's Retrocommissioning Program

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ABSTRACT

Existing commercial buildings represent a largely untapped resource for obtaining energy savings through low-cost operational improvements. These savings can be realized through retrocommissioning (diagnostics and fine-tuning) of existing building automation systems (BAS).

The Sacramento Municipal Utility District (SMUD) implemented a BAS retrocommissioning pilot program to improve the operational and energy efficiency of District buildings. The key objectives of the program were to 1) identify areas for cost-effective energy savings, 2) accomplish immediately feasible improvements, 3) educate building operators to perform ongoing assessment, and 4) identify and recommend additional post-commissioning changes in controls and equipment.

The initial pilot program provided for commissioning services to two large office buildings in SMUD's service territory. Due to enthusiastic responses from several building operators, the program was immediately expanded to include two additional large commercial facilities. Three of the four buildings have participated in other SMUD energy-efficiency programs, and two buildings are already considered models of energy efficiency.

This paper will provide a utility case study of BAS retrocommissioning in existing buildings. The presentation will cover program objectives, building selection criteria, descriptions of the retrocommissioning process and results from the four projects. Included in the findings will be a discussion on how earlier design and engineering assistance provided by SMUD could be enhanced through commissioning. The discussion will conclude with an update on SMUD commissioning activities and program adjustments based on the results of the four retrocommissioning projects.

Introduction

The Sacramento Municipal Utility District (SMUD) is a public-power electric utility serving over 500,000 customers in California's capital city.

SMUD initiated a pilot retrocommissioning program in May 1999. Evidence indicates that a commissioning program designed to spot low-cost operation and maintenance (O&M) improvements can produce significant and immediate value for SMUD customers, demonstrate the beneficial use of public goods funds, and bolster SMUD's reputation as a utility that helps its commercial and industrial (C&I) customers make economical use of electricity. Based on these factors, retrocommissioning appeared to be a very cost-effective method of achieving significant energy savings with a relatively small investment, and SMUD developed and implemented a program.

Definition

Retrocommissioning is generally defined as a systematic process for identifying and implementing low-cost operation and maintenance (O&M) improvements in existing buildings. The SMUD program focuses specifically on adjustments to building control systems in order to bring systems back to the original design intent, and/or to improve equipment operational efficiency.

In addition to identifying low-cost improvements, other repairs and equipment retrofits are often identified through the retrocommissioning process. A systematic process is used to find and fix obvious operational problems and, in the case of more complicated deficiencies, recommend remedies for the building owner to undertake.

Market Overview

Many buildings perform below the efficiency level they were designed to attain due to insufficient commissioning of energy-using equipment and inadequate training of building operators. The energy saving potential is high. Energy savings from retrocommissioning building automation systems (BAS) typically range between 5% and 15%, and can exceed 20% of total building energy use. The simple payback, based on total project costs, is typically within two years, and rarely exceeds four years (Gregerson 1997).

A major impediment to widespread acceptance of retrocommissioning is a general lack of knowledge in the facilities management sector. Building owners believe that their buildings were fully commissioned prior to final acceptance. Contractors typically say that they performed the necessary activities to verify proper installation and operation of all energy-using equipment.

It has been SMUD's experience that new buildings do not undergo a rigorous commissioning process, and that most buildings—even brand-new buildings—do not operate in the highest efficiency ranges. If building occupants are comfortable, and there are no noticeable equipment problems, building engineers have no reason to make operational changes.

Most building engineers take great pride in their work. When provided with reliable information, they will often agree to participate in retrocommissioning activities. SMUD staff had no trouble recruiting candidates for the pilot program. Once the process was explained to facility managers, most were anxious to participate—costs are low compared to the benefits, paybacks are short, the equipment operates more efficiently, and operational reliability is improved.

Program Goals and Objectives

The goals of the retrocommissioning program are to 1) promote market transformation in the retrocommissioning arena and 2) reduce overall building energy consumption through operational improvements.

Goal 1—Promote Market Transformation

Objectives in support of this goal include:

- Educate building operators on the benefits and methods of retrocommissioning.
- Train building operators in the procedures for commissioning existing equipment.
- Train building operators to perform ongoing assessment and provide them with assessment forms and procedures.
- Review various commissioning approaches to determine "best practices."
- Develop case studies to publicize and promote retrocommissioning activities.

For SMUD's retrocommissioning pilot program, the definition of market transformation is "to make retrocommissioning business-as-usual in the large commercial sector." The original intent of the program was to focus on class-A office space only. However, when staff discussed the retrocommissioning process with prospective participants, several customers expressed interest in participating—customers that did not meet the "class-A office" criterion. This became an opportunity to expand the retrocommissioning pilot, and to increase the potential for market transformation beyond class-A office space only.

The market transformation goal focuses on educating building owners and operators about the benefits of retrocommissioning. The initial direction is to provide workshops and to develop case studies for distribution. Depending on the results of the pilot program, other training programs, including building operator certification, may be implemented.

Goal 2—Save Energy Through Operational Improvements

Objectives in support of this goal include:

- Identify areas for cost-effective energy savings through assessment and trending/monitoring of relevant equipment.
- Accomplish feasible improvements as identified in assessment.
- Recommend more extensive, post-commissioning changes in controls and equipment as needed.
- Provide on-site training of building operators.
- Monitor and evaluate results.

Achievement of the second goal is predicated upon successful implementation of retrocommissioning recommendations and sustainability of the measures. To date, the program participants have expressed a desire to implement most of the recommendations, even capital-intensive measures. Follow-up monitoring and evaluation activities will verify the quantity and persistence of energy savings.

Technical Approach

SMUD's initial budget for the pilot program was $50,000, enough to retrocommission two large class-A office buildings. A decision was made to hire two contractors, and allow each to commission one building. Each contractor was allowed to use their own methodologies (within given parameters) to perform commissioning services. SMUD would follow up by evaluating the methodologies of each contractor, review the commissioning recommendations of each, the number of implemented recommendations, and verify the energy savings of each project. Based on this evaluation, SMUD would fine-

tune the commissioning requirements for future projects, and determine whether to expand, maintain, or eliminate the program.

Building selection guidelines were developed and C&I program staff were asked to recommend candidate buildings. Some of the guidelines are subjective. The general selection guidelines include:

- Conditioned floor area over 100,000 ft^2
- Energy intensive building
- BAS of recent vintage with trending capability
- Building staff that has a good relationship with controls vendor
- Building staff with knowledge of BAS and ability to perform follow-up activities
- Building owner/facilities staff with high level of interest in optimizing building operation
- Building owner willing to invest $10,000 to $20,000 to implement improvements

Ten buildings were selected for retrocommissioning consideration. SMUD staff contacted the property managers to verify program interest and followed up with a questionnaire to be completed by the property manager and facilities staffs. Seven buildings were selected for consideration as retrocommissioning candidates. The level of interest among building managers was high enough that SMUD added $50,000 to the budget to include two additional buildings, bringing the total to four. Each contractor was allowed to select two buildings from the list.

Methodology

The retrocommissioning process is a coordinated effort between the contractors and the building operating staff that involves site assessment, monitoring, and evaluation activities. Each project began by developing a scope of work and retrocommissioning plan. Building documentation was then compiled and reviewed by the contractors to gain a better understanding into the various architectural and mechanical details at each site, and operational strategies employed at the respective facilities. The contractors spent at least two days at each facility inspecting equipment, reviewing control code, and performing analysis of the gathered data. A comprehensive monitoring plan was implemented using the BAS trending capability and portable data logging devices. Where monitoring with the BAS or data loggers was not practical, a few select pieces of equipment required additional manual testing. Interview data, written documentation, trend and monitored data, and manual test data for each site were then analyzed. Final conclusions on all findings, cost estimates for repairs and/or upgrades, and potential estimated energy savings calculations were presented to SMUD and the appropriate facility representatives in a final report.

Participating Buildings

The four buildings selected for participation in SMUD's pilot retrocommissioning program covered a fairly wide range of building types, occupancy, and energy intensity. The buildings included an office, a data center, a hospital, and a laboratory facility. Basic details of building characteristics are presented in Table 1, along with a summary of results.

It is observed from Table 1 that the four buildings are of recent vintage with the oldest completed and occupied in 1993. They were all equipped with direct digital controls (DDC) to varying degrees and modern BAS with data monitoring and trending capabilities. It is further noted that three of the buildings have subscribed to SMUD's Commercial New Construction Program which offered construction incentives for energy efficiency features exceeding California's energy efficiency standards (Title 24) by at least 10%. These buildings typically had efficient envelope design and were equipped with high efficiency lighting and HVAC equipment. The hospital (which did not participate in SMUD's New Construction Program) was designed with oversized equipment and with control strategies and operating hours that resulted in high energy intensity. In 1998 the facility staff made significant operational changes from the original design intent. These changes resulted in annual electricity savings of 17% and gas savings of 36%. The energy use figures in Table 1 are for the most recent 12 month period prior to retrocommissioning, and already account for savings due to the above stated operational changes. The high energy use at the laboratory was due to the building's specialized function, which necessitated extended hours of operation. In addition, the facility has a large number of fume hoods and a rifle/pistol firing range which require large quantities of fresh air.

Key findings and Recommendations

The retrocommissioning investigations concentrated on energy equipment operation and control, primarily air conditioning and lighting, where low-cost efficiency improvements are realizable. The review of building documentation, followed by site assessment, monitoring, and evaluation activities, revealed a number of operational and efficiency improvement options for each building. There were similarities in the improvement options for the different buildings, particularly relating to the central plants, air handlers, and air economizer operations. The improvement options were identified as low-cost or capital-intensive based on the anticipated cost of implementing the options relative to the anticipated savings. The low-cost category included improvement options relating to changes in control strategies, run time, sensor location and calibration, valve and damper operation, that could for the most part be performed by the facilities staff and required little or no hardware change-out. Options relying on the addition of fairly major capital equipment or significant modification to existing equipment and had a simple payback in excess of two years were considered as capital intensive.

A summary of the results of the retrocommissioning investigations is included in Table 1. The table gives the number of low-cost and capital-intensive efficiency measures recommended for each of the buildings, along with estimates of the energy savings (electric and gas) that each of the packages of recommended measures would yield. The savings were calculated by using the DOE-2 building energy simulation tool and/or the bin method. The corresponding annual energy cost savings were further estimated in absolute dollar amounts and as percentages of the pre-retrocommissioning annual energy cost. Preliminary estimates for the cost of implementing the recommended package of measures and the associated payback were further established based on prior experience of the facilities staff and/or direct quotes from a BAS vendor/maintenance contractor familiar with the site. It is observed that the number of low-cost efficiency measures proposed for each building varied from 4 to 19, with the corresponding annual energy cost savings ranging from $9,000 to $60,000, or 2.3 –

13.2% of total annual energy costs. These are significant savings considering the low cost of implementation. Estimated simple paybacks to the building owners (not including labor or the cost of the commissioning study) are under two years. When the cost of the commissioning study is included, the simple paybacks range from a low of 0.6 years to a high of 4.4 years (not including facilities staff labor).

Table 1: Building Characteristics and Results Summary of Buildings Participating in the 1999 Retrocommissioning Program

Characteristics & Results Summary	AG Office	VSP Data Center	Children's Hospital	Laboratory Facility
Building Type	Offices and Restaurant	Offices and Data Center	Hospital	Offices and Laboratory
Year Building Occupied	1995	1993	1997	1997
Conditioned Floor Area – ft^2	351,450	150,000	300,000	94,000
Participation in SMUD's New Construction Program	Yes	Yes	No	Yes
Pre-retrocommissioning Energy Use				
Electricity Use Intensity ($kWh/ft^2/yr$)	14.2	31.6	33.7	61.9
Electric Peak Load ($W/ft^{2)}$	3.93	7.52	6.72	13.4
Gas Use Intensity ($therm/ft^2/yr$)	0.22	0.23	0.86	1.95
Low Cost Efficiency Measures				
Number of Proposed Measures	7	11	19	4
Estimated Electricity Savings (kWh/yr)	167,800	523,704	809,302	629,348
Estimated Gas Savings (therms/yr)	4,520	19,103	12,150	67,994
Estimated Annual Energy Cost Savings	$ 9,060	$ 37,561	$ 53,511	$ 60,794
% Annual Cost Savings (vs. 1998)	2.3%	10.7%	6.7%	13.2%
Expected Cost to Implement Measures	$ 15,000	$ 9600	$ 29,600	$ 4,300
Simple Payback to Building Owner	1.7 yrs	0.26 yr	0.6 yr	0.07 yr
Simple Payback Including Study Cost	4.4 yrs	0.92 yr	1.1 yr	0.55 yr
Capital Intensive Measures				
Number of Proposed Measures	2	6	10	4
Estimated Electricity Savings (kWh/yr)			2,059,562	392,100
Estimated Gas Savings (therms/yr)			41,671	22,770
Estimated Energy Cost Savings/yr			$ 125,410	$ 41,506
% Annual Cost Savings (vs. 1998)			15.7%	9.0%
Estimated Cost to Implement Measures			$ 233,750	$ 88,530
Simple Payback to Building Owner	NA	NA	1.9 yrs	2.1 yrs

Areas of Low-Cost Improvement

- Air handler operation sequence, run time, and procedure for enabling operation outside of normal working hours
- Number, location, and accuracy of outside air temperature sensors and their use in economizer operation
- Proper staging and modulation of supply, exhaust, and return air dampers
- Cooling and heating coil operation and valve modulation to maintain supply temperature set-point
- Chilled water, condenser water, and supply air temperature reset routines

- Duct static pressure sensor location, accuracy, and sensor use in air flow control
- Duct static pressure reset while maintaining a maximum terminal variable air volume (VAV) box damper position at 90 – 95% open
- Staging of boiler and hot water pump operation and hot water supply temperature reset
- Adjustment of proportional and integral control gains to prevent "hunting" in valve and damper operation
- Lighting schedules, override duration, and staging with occupancy sensors

Capital-Intensive Improvement Options

- Install variable speed drives (VSDs) on large centrifugal chillers to improve part load operation
- Install VSDs on pumps, relief fans and cooling tower fans
- Upgrade VAV boxes to allow dynamic reset of duct static based on maximum terminal damper position
- Employ occupancy-sensor based VAV box control to limit outside air ventilation
- Remove flow restricting valves and dampers and substitute with impeller trimming and/or VSDs
- Install additional automatic lighting controls
- Upgrade BAS with graphic interface module

The investigations also produced a number of observations and proposed improvements that did not have much energy savings potential—and in some cases might even increase energy use—but that could improve equipment operation, occupant comfort, indoor air quality, and life and reliability of equipment. These observations were communicated to the facilities staff for possible implementation as seen fit.

It is worthy to note that the retrocommissioning investigations were conducted with close consultation and cooperation of concerned facilities staff at each building. This created a good atmosphere for understanding and appreciation of the evaluation process and the findings. It further allowed the transfer of knowledge and experience to the facilities staff responsible for maintaining the building's energy systems and ensures continued optimal equipment operation. It came as no surprise that the facilities management and staff embraced the findings and committed to implement all of the low-cost measures and will work towards implementing the capital-intensive measures as resources allow.

The implementation phase involved a discussion with each building's facilities management and staff of the recommendations, as well as the practical and financial implications of implementation. The recommendations were then prioritized and an execution plan developed. A number of the recommendations involving simple adjustments to equipment and control strategies were performed immediately. Most of the other recommendations are planned for implementation in the near future.

SMUD Follow-up

New Construction Follow-Up

Three of the four buildings that went through the retrocommissioning process participated in SMUD's energy efficiency New Construction Program: the office, the data center, and the laboratory facility. These buildings were constructed with high-efficiency lighting and air conditioning equipment. Other measures included (not necessarily in each building) daylighting controls, occupancy sensors, high-efficiency windows, variable frequency drives on fans and pumps, and additional roof insulation.

Even with the installation of high-efficiency equipment during the construction process, retrocommissioning savings were readily available a few years after building occupancy. This indicates the need for a commissioning component in SMUD's New Construction Program. If the commissioning process can be introduced early in the building design process, building owners and tenants will realize additional energy savings from the first day of occupancy. As part of the 2001 program planning process, SMUD will investigate ways to include commissioning in the New Construction Program.

Retrocommissioning Follow-Up

Metrics indicating program success include implementation of recommended improvements, cost-effective energy and capacity savings, and increased knowledge of retrocommissioning among building managers and operators. It is important that the experience and results be made available to SMUD's large commercial/institutional customers and to the building community at large to increase the knowledge base, develop increased interest in BAS retrocommissioning activities, and achieve energy savings. SMUD is planning to maintain follow-up and evaluation of the impact of the retrocommissioning investigations and to diffuse information on its findings.

SMUD will follow up on the progress of implementing the recommended improvements, the extent of realized savings, and the satisfaction of the facilities management and staff with the outcome. This will be done through occasional interviews of the facilities management and staff coupled with some monitoring, where necessary, to verify performance. Monitoring and trending using the BAS system will also be conducted to verify performance improvements associated with the implemented recommendations. This will verify proper equipment operation as well as persistence of the savings.

The program results to date are encouraging even though many measures have yet to be implemented. Facilities management and staff are pleased with the experience, and have already benefited from the initial modifications. The program has proved to be sufficiently beneficial to warrant continuation through the year 2000 with the retrocommissioning of two additional buildings.

As part of SMUD's effort to increase awareness on the meaning and value of commissioning, SMUD hosted a half-day workshop on the subject last autumn and is diffusing information on the experience through conference presentations and papers. This effort will continue during this year's program with the goal of effecting market transformation.

Conclusions

The retrocommissioning of four diverse commercial and institutional buildings resulted in the identification and recommendation of a number of low-cost efficiency

improvements. Most of the measures are presently in the process of implementation. The measures are estimated (based on simulations and engineering estimates) to result in total energy savings amounting to 2.3% to 13.2% of annual energy use. Other identified measures are expected to result in improved equipment operation, comfort, indoor air quality, and life and reliability of equipment. The low-cost measures are projected to provide simple paybacks to the building owner of less than two years (not including labor costs or the cost of the commissioning study).

The amount of energy and capacity savings remains to be verified through follow-up and evaluation. SMUD monitoring and evaluation staff will begin evaluating the pilot program during the fourth quarter, 2000. Indications are that the savings are realizable and that facility personnel will implement and maintain most, if not all, of the identified low-cost measures. Several capital-intensive measures are also scheduled for implementation due to retrocommissioning. The pilot program has been successful. Projections show cost-effective energy savings and commissioning education has been provided to participating facilities personnel. In order to promote market transformation on a larger scale, building managers and operators need to be informed of the benefits of retrocommissioning. By providing workshops and educational forums, and developing and promoting retrocommissioning case studies for facilities personnel, retrocommissioning activities are expected to grow—without the need for significant cash infusions by utilities.

References

Gregerson, J. 1997. "Cost Effectiveness of Commissioning 44 Existing Buildings." *In Proceedings of the National Conference on Building Commissioning.* Huntington Beach, CA